INSPIRE
Infrastructure for Spatial Information in Europe

D2.8.II/III.4 Data Specification on Geology – Draft Guidelines

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Foreword
How to read the document?

This document describes the “INSPIRE data specification on <Theme Name> - Guidelines” as developed by the Thematic Working Group *Geology* using both natural and a conceptual schema language. The data specification is based on a common template used for all data specifications and has been harmonised with the other Annex I data specifications by a joint editing team.

This document provides guidelines for the implementation of the provisions laid down in the draft Implementing Rule for spatial data sets and services of the INSPIRE Directive.

This document includes two executive summaries that provide a quick overview of the INSPIRE data specification process in general, and the content of the data specification on *Geology* in particular. We highly recommend that managers, decision makers, and all those new to the INSPIRE process and/or information modelling should read these executive summaries first.

The UML diagrams (in Chapter 5) offer a rapid way to see the main elements of the specifications and their relationships. The definition of the spatial object types, attributes, and relationships are included in the Feature Catalogue (also in Chapter 5). People having thematic expertise but not familiar with UML can fully understand the content of the data model focusing on the Feature Catalogue. Users might also find the Feature Catalogue especially useful to check if it contains the data necessary for the applications that they run. The technical details are expected to be of prime interest to those organisations that are/will be responsible for implementing INSPIRE within the field of *Geology.*

The technical provisions and the underlying concepts are often illustrated by examples. Smaller examples are within the text of the specification, while longer explanatory examples are attached in the annexes.

In order to distinguish the INSPIRE spatial data themes from the spatial object types, the INSPIRE spatial data themes are written in *italics.*

Interoperability of Spatial Data Sets and Services – General Executive Summary

The challenges regarding the lack of availability, quality, organisation, accessibility, and sharing of spatial information are common to a large number of policies and activities and are experienced across the various levels of public authority in Europe. In order to solve these problems it is necessary to take measures of coordination between the users and providers of spatial information. The Directive 2007/2/EC of the European Parliament and of the Council adopted on 14 March 2007 aims at establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) for environmental policies, or policies and activities that have an impact on the environment.

INSPIRE will be based on the infrastructures for spatial information that are created and maintained by the Member States. To support the establishment of a European infrastructure, Implementing Rules addressing the following components of the infrastructure are being specified: metadata, interoperability of spatial data themes (as described in Annexes I, II, III of the Directive) and spatial data services, network services and technologies, data and service sharing, and monitoring and reporting procedures.

INSPIRE does not require collection of new data. However, after the period specified in the Directive[1] Member States have to make their data available according to the Implementing Rules.

Interoperability in INSPIRE means the possibility to combine spatial data and services from different sources across the European Community in a consistent way without involving specific efforts of humans or machines. It is important to note that "interoperability" is understood as providing access to spatial data sets through network services, typically via Internet. Interoperability may be achieved by either changing (harmonising) and storing existing data sets or transforming them via services for publication in the INSPIRE infrastructure. It is expected that users will spend less time and efforts on understanding and integrating data when they build their applications based on data delivered within INSPIRE.

In order to benefit from the endeavours of international standardisation bodies and organisations established under international law their standards and technical means have been referenced, whenever possible.

To facilitate the implementation of INSPIRE, it is important that all stakeholders have the opportunity to participate its specification and development. For this reason, the Commission has put in place a consensus building process involving data users, and providers together with representatives of industry, research and government. These stakeholders, organised through Spatial Data Interest Communities (SDIC) and Legally Mandated Organisations (LMO)[2], have provided reference materials, participated in the user requirement and technical[3] surveys, proposed experts for the Data Specification Drafting Team[4] and Thematic Working Groups[5], expressed their views on the drafts of

[1] For Annex I data: within two years of the adoption of the corresponding Implementing Rules for newly collected and extensively restructured data and within 5 years for other data in electronic format still in use

[2] Number of SDICs and LMOs on 21/11/2008 was 276 and 162 respectively

[3] Surveys on unique identifiers and usage of the elements of the spatial and temporal schema,

[4] The Data Specification Drafting Team has been composed of experts from Austria, Belgium, Czech Republic, France, Germany, Greece, Italy, Netherlands, Norway, Poland, Switzerland, UK, and the European Environmental Agency

[5] The Thematic Working Groups of Annex I themes have been composed of experts from Belgium, Czech Republic, Denmark, France, Finland, Germany, Hungary, Italy Netherland, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, UK, the European Commission, and the European Environmental Agency

the technical documents of the data specification development framework[6] and are invited to comment the draft Implementing Rule on Interoperability of Spatial Data Sets and Services.

The development framework elaborated by the Data Specification Drafting Team aims at keeping the data specifications of the different themes coherent. It summarises the methodology to be used for the data specifications and provides a coherent set of requirements and recommendations to achieve interoperability. The pillars of the framework are four technical documents:

- The Definition of Annex Themes and Scope[7] describes in greater detail the spatial data themes defined in the Directive, and thus provides a sound starting point for the thematic aspects of the data specification development.

- The Generic Conceptual Model[8] defines the elements necessary for interoperability and data harmonisation including cross-theme issues. It specifies requirements and recommendations with regard to data specification elements of common use, like the spatial and temporal schema, unique identifier management, object referencing, a generic network model, some common code lists, etc. Those requirements of the Generic Conceptual Model that are directly implementable will be included in the Implementing Rule on Interoperability of Spatial Data Sets and Services.

- The Methodology for the Development of Data Specifications[9] defines a repeatable methodology. It describes how to arrive from user requirements to a data specification through a number of steps including use-case development, initial specification development and analysis of analogies and gaps for further specification refinement.

- The "Guidelines for the Encoding of Spatial Data"[10] defines how geographic information can be encoded to enable transfer processes between the systems of the data providers in the Member States. Even though it does not specify a mandatory encoding rule it sets GML (ISO 19136) as the default encoding for INSPIRE.

Based on the data specification development framework, the Thematic Working Groups have created the INSPIRE data specification for each Annex I theme. The data specifications follow the structure of "ISO 19131 Geographic information - Data product specifications" standard. They include the technical documentation of the application schema, the spatial object types with their properties, and other specifics of the spatial data themes using natural language as well as a formal conceptual schema language[11].

A consolidated model repository, feature concept dictionary, and glossary are being maintained to support the consistent specification development and potential further reuse of specification elements. The consolidated model consists of the harmonised models of the relevant standards from the ISO 19100 series, the INSPIRE Generic Conceptual Model, and the application schemas[12] developed for each spatial data theme. The multilingual INSPIRE Feature Concept Dictionary contains the definition and description of the INSPIRE themes together with the definition of the spatial object types present in the specification. The INSPIRE Glossary defines all the terms (beyond the spatial object types) necessary for understanding the INSPIRE documentation including the terminology of other components (metadata, network services, data sharing, and monitoring).

By listing a number of requirements and making the necessary recommendations, the data specifications enable full system interoperability across the Member States, within the scope of the

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[6] Four documents describing common principles for data specifications across all spatial data themes. See further details in the text.
[7] *http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.3_Definition_of_Annex_Themes_and_scope_v3.0.pdf*
[8] *http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.5_v3.1.pdf*
[9] *http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.6_v3.0.pdf*
[10] *http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.7_v3.0.pdf*
[11] UML – Unified Modelling Language
[12] Conceptual models related to specific areas (e.g. INSPIRE themes)

application areas targeted by the Directive. They are published as technical guidelines and provide the basis for the content of the Implementing Rule on Interoperability of Spatial Data Sets and Services for data themes included in Annex I of the Directive. The Implementing Rule will be extracted from the data specifications keeping in mind short and medium term feasibility as well as cost-benefit considerations. The Implementing Rule will be legally binding for the Member States.

In addition to providing a basis for the interoperability of spatial data in INSPIRE, the data specification development framework and the thematic data specifications can be reused in other environments at local, regional, national and global level contributing to improvements in the coherence and interoperability of data in spatial data infrastructures.

Geology – Executive Summary

In the INSPIRE context Geology could be seen as a "reference data theme" as it provides information for several themes of annex III: Mineral resources, Natural Risk Zones, Soil, Energy resources, and it has a specific relationship with one of the most important natural resources, the water, through groundwater bodies and aquifers. Geomorphology describes the earth's present-day surface, the processes creating its geometry, and the deposits generated as a result of the activity of some processes.

The use of geological data

Geological data are used in various domains related to the underground knowledge:

- Detecting geo-hazards
- Ensuring the safe disposal of wastes, nuclear wastes, Carbon Capture and Storage
- Ensuring the safe construction of buildings
- Providing information for environmental planning
- Providing information for natural resources exploration
- Vulnerability of the underground to contamination
- Aid in depicting indicators for climatic change
- Providing construction material and minerals

and for groundwater and aquifers:

- Water supply (water abstraction)
- Groundwater resources (water availability)
- Providing base flow for rivers, wetlands
- Protecting ecosystems dependent on groundwater
- Groundwater quality and quantity assessment
- Transboundary groundwater management

How geoscientists could provide this useful information?

Geological information provides basic knowledge about the physical properties and composition of the geologic materials (rocks and sediments) outcropping at the land's surface and forming the underground, and about their structure and their age. It also provides knowledge about aquifers, i.e. subsurface units of rocks or sediments of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater. Knowledge about landforms is also provided.

The main product delivered by geologists for the users is a geological map which is the result of an **interpretation** of the observations and measurements made on rocks and sediments, on and under the surface. Because the rocks forming the subsurface are visible or accessible only on very small parts of the surface, the outcrops, the geologists have to interpret these observations and measurements to group rocks in geologic units, and to connect other information observed locally to identify the general geological structure.

3D geological models could also be developed both at a regional scale and at a very local scale.

Geologists group the rocks in geologic units according to their properties, their structure and their age, To understand the composition, the structure and the properties of the materials in the underground, , many methodologies providing many kind of data have been developed.

AT the outcrops, locations where rocks are visible, geologists make direct observations of the rocks and measurements of their structure, and take samples. The analyses of samples provides values for physical properties, as well as information on the chemical and mineralogical composition of the rocks, and data relative to their age.
Geophysical surveys provide values of physical properties of rocks (like density, porosity, magnetic susceptibility, …), regardless their organization as geologic units. Geophysical boundaries may or may not coincide with geological boundaries, depending on the changes of physical properties within and

outside the geological units. Geophysics provides extra - quite often the only - information on the organization of the units in the subsurface. These results are processed by geophysicists to deliver the spatial distribution (1D, 2D or 3D) of the property. The spatial property distributions are then interpreted by geologists to build geological models of the subsurface for instance to detect hydrocarbon bearing structures or zones of mineral resources.

Geochemistry surveys, geochemical measurements and analyses provide information about the chemical composition of samples. Satellite images, aerial photographs and other airborne surveys are used to improve the outlines of geologic units, geologic structures, and geomorphologic features. Boreholes provide knowledge about the underground, and according to the reasons rationale by which a borehole is made, some or many rock properties are observed or measured.

All this information are is interpreted to make the geological map, and in some cases 3D models. The landforms (geomorphologic features) are often indicated on general geological maps, and are detailed on specific, applied geomorphological maps.

Which geological and geophysical data to provide through INSPIRE?

Several main categories of data could be identified:
- Geological and geophysical Observations and Measurements
- The lithology and composition of rocks and samples, collected from them
- Models of properties values (variations in space of a property value) made from observations and measurements
- Geological interpretation based on observations and measurements, in the form of maps and models

The users of Geology in INSPIRE are mainly geoscientists of other data themes (of Annex III) as Mineral Resources, Natural Risk Zones, Soil, Energy resources, and the identified use cases request to deliver various geological information. The TWG suggests to deliver this information with a core data model for the basic knowledge, and to use the full model to meet requirements from the use cases with more properties.
Some domains of Geology are not addressed by this INSPIRE model as they are for geologists, but the GeoSciML data model, developed by the community of geologists, can be used for these domains.

The core data model contains:
- Geologic Features with Geological Units, Geological Structures, and Geomorphologic Features. The geometry of these features is described in Mapped Features, the geometry of which is included in geological maps and profiles in the form of points, lines and polygons.
- The lithology and material composition of rock units
- Borehole details, such as location and purpose
- Geophysical measurements, and models

The full data model contains:
- more properties about Geologic Features: Age, Physical properties
- more properties about Geologic Structures: displacement
- more properties about Boreholes: about the borehole itself and the logs
- A seismic example as an example of the use of Observations & Measurements

In this version of data specification we do not provide a data model to deliver raw data like geophysical raw data, geochemical data, geomechanical data, and borehole observations and measurements. The ISO standard Observations and Measurements could be used by data providers to deliver such data.
3D Geological models of properties values (variations in space of a property value in the form of grid coverages) are not taken into account.

Specific issue about the rock type

A geologic unit represents a body of material in the Earth; this earth material is composed of several types of rocks, or minerals, with various proportions, and ideally defined according to physical and

chemical properties but genesis information is also taken into account. The rock material, whose name is indicated in the property “lithology”, could have been transformed partially or totally by alteration or other processes. As a result lithology code list contains a lot of values to describe these natural objects (several hundreds).
To present geologic units in a way easier to understand it is possible to classify them according to a more simple classification (using the controlled concept modeling pattern) describing the main rock types.

The Geology data model offers these two options:
- A detailed description of earth material to meet the requirements of the use cases (the need to know various properties of rocks)
- A simple classification of geologic units according to the type of rocks

(See Annex D for the detailed description of this issue).

Basic geological knowledge and applied maps

As mentioned above, Geology is used by other thematic domains which are interested only in some properties of the underground (to prevent landslides, to insure safe disposal of wastes, …). Geological surveys provide the knowledge they have about the Earth. A process must be run by Geological Surveys or thematic experts to transform this basic knowledge into specific maps (named applied maps) required by thematic users.
As very often the needs of thematic users concern local area, the basic knowledge must be completed by new data related to specific properties (for example to know the porosity of the local rocks to contribute to the assessment of a landslide).
The INSPIRE Geology model provides elements to build applied maps but does not describe these applied features.

Aquifers and groundwater bodies

Hydrogeology describe the flow, condition of occurrence and behavior of water in underground environment. It is a science located between hydrology and geology, while both have a strong influence on the groundwater resources creation. Hydrological processes are responsible e. g. for quantity of water supply by the recharge area to aquifers. On the other hand the physical properties and composition of the geologic materials (rocks and sediments) create the main environment for groundwater flow and storage, rocks and sediments also influent on groundwater quality in terms of their chemical composition.

The basic idea of INSPIRE model for groundwater is to identify two basic elements: Aquifer System (dependent on the geological condition) and Groundwater Flow System. Both components create Hydrogeological System (see annex C for a detailed description of this domain).

Table of contents

1 Scope

This document specifies a harmonised data specification for the spatial data theme *Geology* as defined in Annex II/III of the INSPIRE Directive.

This data specification provides the basis for the drafting of Implementing Rules according to Article 7 (1) of the INSPIRE Directive [Directive 2007/2/EC]. The entire data specification will be published as implementation guidelines accompanying these Implementing Rules.

2 Overview

2.1 Name and acronyms

INSPIRE data specification for the theme Geology

2.2 Informal description

Definition:

Geology characterised according to composition and structure. Includes bedrock, aquifers and geomorphology

<definition> [Directive 2007/2/EC]

Description:

From the definition, we detail each word. **Geology** is the study of the past and present aspects of the Earth, including its history and life on Earth.
The **composition** of an earth material describes what it consists of (its components), both the weight percentage of elements or molecules (chemical composition), and the species and number of particles, e.g. minerals (mineralogical composition), clasts and fossils.
The **structure** of an earth material describes the physical arrangements of its components. A geologic structure is a configuration of matter in the Earth based on describable inhomogeneity, pattern, or fracture in an earth material.
The composition and structure of earth materials

- is reflected by their physical properties (e.g. density, porosity, and mechanical, magnetic, electrical, seismic and hydraulic properties)
- influences geological processes (genesis, fracturing, alteration)
- controls the properties of aquifers
- controls the morphology of the landscape
- controls their use as a natural resources
- determines their behaviour during natural and industrial processes

The **bedrock** is a general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material. A British syn. of the adjectival form is solid, as in solid geology.

Aquifer is a porous rock structure within which water travels and is stored. Aquifers may be shallow, a few meters in depth, or very deep being several hundred meters in depth.

Groundwater is all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil. This zone is commonly referred to as an aquifer which is a subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow a significant flow of groundwater or the abstraction of significant quantities of groundwater.

Water body is a discrete and significant element of surface water such as a river, lake or reservoir, or a distinct volume of groundwater within an aquifer.

Generally the groundwater body is not exactly correlated with main (deeper) groundwater aquifers because it was based on the surface water basins. So it means that not always aquifer = groundwater body (GWB) (the methodology differs in different member states).
Geomorphology provides basic knowledge about the present shape of the sub aerial and submerged parts of the Earth surface, about its dynamics (genesis and involved processes) and about the physical, mechanical and chemical properties and the behaviors of their constitutive materials.

In the INSPIRE context Geology could be seen as a “reference data theme” as it provides information for several themes of annex III: Mineral resources, Natural Risk Zones, Soil, Energy resources, and it has a specific relationship with one of the main important natural resource, the water, through groundwater bodies and aquifers.

To identify the most relevant object types and their properties, the TWG has analysed reference material and user requirements, and has provided a list of “Examples of use” of geology:

- Detecting geo-hazards (geology + geomorphology)
- Ensuring the safe disposal of wastes, nuclear wastes, Carbon Capture and Storage
- Ensuring the safe construction of buildings
- Providing information for environmental planning
- Providing information for natural resources exploration
- Vulnerability underground to contamination
- Aid in depicting indicators for climatic change
- Providing construction material and minerals
- …

and for groundwater and aquifers:

- Water supply (water abstraction)
- Groundwater resources (water availability)
- Providing base flow for rivers, wetlands
- Protecting ecosystems dependent on groundwater
- Groundwater quality and quantity assessment
- Transboundary groundwater management

(All these examples are described in detail in the TWG document “Examples of use” in circa)

This overview shows the wide range of use with various sets of rock properties according to the use: a geologist in charge of mineral prospection, or mining waste protection, does not request the same information about rocks than an engineer dealing with natural hazards more interested on underground stability.
So the TWG decided to provide two application schemas: one related to the common object types and common properties requested by all examples of use (the basic geological knowledge about rocks under our feet), and another one to address more properties but optional.

This specification identifies two application schemas of Geology:

- The core schema: able to provide the basic geological knowledge on an area, with a limited number of attributes,
- Full schema: able to provide the basic geological knowledge but also more attributes describing rock composition and structure to meet requirements from use cases.

2.3 Normative References

[Directive 2007/2/EC] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)

[ISO 19107] EN ISO 19107:2005, Geographic Information – Spatial Schema

[ISO 19108] EN ISO 19108:2005, Geographic Information – Temporal Schema

[ISO 19108-c] ISO 19108:2002/Cor 1:2006, Geographic Information – Temporal Schema, Technical Corrigendum 1

[ISO 19111] EN ISO 19111:2007 Geographic information - Spatial referencing by coordinates (ISO 19111:2007)

[ISO 19113] EN ISO 19113:2005, Geographic Information – Quality principles

[ISO 19115] EN ISO 19115:2005, Geographic information – Metadata (ISO 19115:2003)

[ISO 19118] EN ISO 19118:2006, Geographic information – Encoding (ISO 19118:2005)

[ISO 19123] EN ISO 19123:2007, Geographic Information – Schema for coverage geometry and functions

[ISO 19135] EN ISO 19135:2007 Geographic information – Procedures for item registration (ISO 19135:2005)

[ISO 19138] ISO/TS 19138:2006, Geographic Information – Data quality measures

[ISO 19139] ISO/TS 19139:2007, Geographic information – Metadata – XML schema implementation

[OGC 06-103r3] Implementation Specification for Geographic Information - Simple feature access – Part 1: Common Architecture v1.2.0

NOTE This is an updated version of "EN ISO 19125-1:2006, Geographic information – Simple feature access – Part 1: Common architecture". A revision of the EN ISO standard has been proposed.

[Regulation 1205/2008/EC] Regulation 1205/2008/EC implementing Directive 2007/2/EC of the European Parliament and of the Council as regards metadata

[Regulation 2000/60/EC] DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000 establishing a framework for Community action in the field of water policy

[Regulation 2006/118/EC] DIRECTIVE 2006/118/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006 on the protection of groundwater against pollution and deterioration

Web sites describing the data model standard:

- **GeoSciML:** http://www.geosciml.org
- **GWML:** http://ngwd-bdnes.cits.rncan.gc.ca/service/api_ngwds/en/gwml.html

2.4 Terms and definitions

Terms and definitions necessary for understanding this document are defined in the INSPIRE Glossary[13].

In addition the following terms and definitions are used: (delete if no additional terms are defined)

(1) GeologicFeature
A GeologicFeature can be either a Geologic Unit, a Geologic Structure, a Geomorphologic Unit or a Hydrogeologic Unit, linked to a Mapped Feature describing the geometry.

(2) MappedFeature
A MappedFeature can be considered an occurrence, such as a polygon on a geologic map, of a real world GeologicFeature the full extent of which is unknown. It is independent of geometry, so the same GeologicFeature can have different MappedFeature instances representing mapped polygons at different scales or a modelled volume, for example. Each MappedFeature, however, can represent only one GeologicFeature.

(3) Geologic Unit
A Geologic Unit is a notional unit, complete and precise extent of which is inferred to exist. Spatial properties are only available through association with a MappedFeature. GeologicUnits can be formal units (i.e. formally adopted and named in the official lexicon), informal units (i.e. named but not promoted to the lexicon) and unnamed units (i.e. recognisable and described and delineable in the field but not otherwise formalised).

(4) Geologic Structure
A Geologic Structure, for the INSPIRE context, considers only faults.

(5) Hydrogeologic Unit
A Hydrogeologic Unit is a subset of Geologic Unit and means any soil of rock unit or zone which by virtue of its porosity or permeability, or lack thereof, has a distinct influence on the storage or movement of groundwater.

(6) Aquifer
An Aquifer is formation, group of formations, or part of a formation that contains sufficient saturated, pemeable material to yield significant quantities of water to wells and springs. An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well.

2.5 Symbols and abbreviations

2.6 Notation of requirements and recommendations

To make it easier to identify the mandatory requirements and the recommendations for spatial data sets in the text, they are highlighted and numbered.

[13] The INSPIRE Glossary is available from http://inspire-registry.jrc.ec.europa.eu/registers/GLOSSARY

IR Requirement X	Requirements that are reflected in the Implementing Rule on interoperability of spatial data sets and services are shown using this style.

DS Requirement X	Requirements that are not reflected in the Implementing Rule on interoperability of spatial data sets and services are shown using this style.

Recommendation 1 Recommendations are shown using this style.

2.7 Conformance

DS Requirement 1	Any dataset claiming conformance with this INSPIRE data specification shall pass the requirements described in the abstract test suite presented in Annex A.

3 Specification scopes

This data specification has only one scope, the general scope.

4 Identification information

Table 1 – Information identifying the INSPIRE data specification *Geology*

Title	INSPIRE data specification *Geology*
Abstract	Geological information provides basic knowledge about the physical properties and composition of the rocks and sediments in the underground, and their structure. It also provides knowledge about aquifers, i.e. subsurface units of rocks or sediments of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater. Knowledge about landforms are also provided.
Topic categories	geoscientificInformation
Geographic description	This INSPIRE data specification covers spatial data sets which relate to an area where a Member State has and/or exercises jurisdictional rights.
Purpose *(Optional)*	The purpose of this document is to specify a harmonised data specification for the spatial data theme *Geology* as defined in Annex II/III of the INSPIRE Directive. Information about geology, including aquifers and geomorphology, is provided with the purpose to support several themes in Annex III: Mineral resources, Natural Risk Zones, Soil, Energy resources, and it has a specific relationship with one of the main important natural resources, the water, through groundwater bodies and aquifers
Spatial representation type *(Optional)*	vector | grid
Spatial	National level 1:250 000 to 1 000 000

resolution *(Optional)*	Regional level 1:250 000 to 1:25 000 Local level >1:25 000
Supplemental information *(Optional)*	These are the key Feature Types of the theme Geology: A GeologicFeature can be either a GeologicUnit (e.g. a granite body), a GeologicStructure (e.g. a fault) or a GeomorphologicFeature (e.g. an erosional channel), linked to a MappedFeature describing the geometry. A GroundwaterBody is a kind of WaterBody, which is contained within an Aquifer (a kind of GeologicUnit, e.g. a porous sandstone). The GroundwaterBody has a WaterQualityDescription. Boreholes are also linked to MappedFeatures

5 Data content and structure

IR Requirement 1 Spatial data sets related to the theme **Geology** shall be provided using the spatial object types and data types specified in the application schema(s) in this section.

IR Requirement 2 Each spatial object shall comply with all constraints specified for its spatial object type or data types used in values of its properties, respectively.

Recommendation 1 The reason for a void value should be provided where possible using a listed value from the VoidValueReason code list to indicate the reason for the missing value.

NOTE The application schema specifies requirements on the properties of each spatial object including its multiplicity, domain of valid values, constraints, etc. All properties have to be reported, if the relevant information is part of the data set. Most properties may be reported as “void”, if the data set does not include relevant information. See the Generic Conceptual Model [INSPIRE DS-D2.5] for more details.

5.1 Basic notions

This section explains some of the basic notions used in the INSPIRE application schemas. These explanations are based on the GCM [DS-D2.5].

5.1.1 Placeholder and candidate types

INSPIRE data specifications may refer to types that thematically belong and might be fully specified in future (i.e. Annex II or III) spatial data themes. Two kinds of such types are distinguished:

– A *placeholder type* is a type that acts as a placeholder for a type (typically a spatial object type) that will be specified as part of a future spatial data theme, but is already used as a value type of an attribute or association role in this data specification.

Placeholder types receive the stereotype «placeholder» and are placed in the application schema package of the future spatial data theme where they thematically belong. A definition for the placeholder type is specified based on the requirements of the Annex I theme. This definition shall be taken into account when the type is specified in the future spatial data theme,

and the attributes or association roles in this data specification that have the placeholder as a value type shall be updated if necessary.

- A *candidate type* is a type (typically a spatial object type) for which already a preliminary specification is given. Candidate types do not receive a specific stereotype and is placed in the application schema package of the future spatial data theme where they thematically belong. A definition for the type and its attributes and association roles are specified based on the requirements of the Annex I theme.

  This specification shall be taken into account in the specification work of the Annex II or III theme. If the type cannot be incorporated in the Annex II or III data specification according to its preliminary specification, it shall be moved into the application schema of the Annex I theme where it has first been specified. In this case, the attributes or association roles in this data specification that have the type as a value type shall be updated if necessary.

Placeholders and candidate types are listed in a separate subsection of the Feature Catalogue.

5.1.2 Voidable characteristics

If a characteristic of a spatial object is not present in the spatial data set, but may be present or applicable in the real world, the property shall receive this stereotype.

If and only if a property receives this stereotype, the value of *void* may be used as a value of the property. A *void* value shall imply that no corresponding value is contained in the spatial data set maintained by the data provider or no corresponding value can be derived from existing values at reasonable costs, even though the characteristic may be present or applicable in the real world.

It is possible to qualify a value of void in the data with a reason using the VoidValueReason type. The VoidValueReason type is a code list, which includes the following pre-defined values:

- *Unpopulated*: The characteristic is not part of the dataset maintained by the data provider. However, the characteristic may exist in the real world. For example when the “elevation of the water body above the sea level” has not been included in a dataset containing lake spatial objects, then the reason for a void value of this property would be ‘Unpopulated’. The characteristic receives this value for all objects in the spatial data set.
- *Unknown*: The correct value for the specific spatial object is not known to, and not computable by the data provider. However, a correct value may exist. For example when the “elevation of the water body above the sea level” *of a certain lake* has not been measured, then the reason for a void value of this property would be ‘Unknown’. This value is applied on an object-by-object basis in a spatial data set.

NOTE It is expected that additional reasons will be identified in the future, in particular to support reasons / special values in coverage ranges.

The «voidable» stereotype does not give any information on whether or not a characteristic exists in the real world. This is expressed using the multiplicity:

- If a characteristic may or may not exist in the real world, its minimum cardinality shall be defined as 0. For example, an if an Address may or may not have a house number, the multiplicity of the corresponding property shall be 0..1.
- If at least one value for a certain characteristic exists in the real world, the minimum cardinality shall be defined as 1. For example, if an Administrative Unit always has at least one name, the multiplicity of the corresponding property shall be 1..*.

In both cases, the «voidable» stereotype can be applied. A value (the real value or void) only needs to be made available for properties that have a minimum cardinality of 1.

5.1.3 Code lists and Enumerations

5.1.3.1. Style

All code lists and enumerations use the following modelling style:

- No initial value, but only the attribute name part, is used.
- The attribute name conforms to the rules for attributes names, i.e. is a lowerCamelCase name. Exceptions are words that consist of all uppercase letters (acronyms).

5.1.3.2. Governance

Two types of code lists can be distinguished:

- code lists that shall be managed centrally in the INSPIRE code list register and only values from that register may be used, and
- code lists that may be extended by data providers.

In the UML model, all code lists that are centrally managed have the tagged value "codeList" with the preliminary value "urn:x-inspire:def:codeList:INSPIRE:<name of the class>".

5.1.4 Stereotypes

In the application schemas in this sections several stereotypes are used that have been defined as part of a UML profile for use in INSPIRE [INSPIRE DS-D2.5]. These are explained in Table 2 below.

Table 2 – Stereotypes (adapted from [INSPIRE DS-D2.5])

Stereotype	Model element	Description
applicationSchema	Package	An INSPIRE application schema according to ISO 19109 and the Generic Conceptual Model.
featureType	Class	A spatial object type.
type	Class	A conceptual, abstract type that is not a spatial object type.
dataType	Class	A structured data type without identity.
union	Class	A structured data type without identity where exactly one of the properties of the type is present in any instance.
enumeration	Class	A fixed list of valid identifiers of named literal values. Attributes of an enumerated type may only take values from this list.
codeList	Class	A flexible enumeration that uses string values for expressing a list of potential values.
placeholder	Class	A placeholder class (see definition in section 5.1.1).
voidable	Attribute, association role	A voidable attribute or association role (see definition in section 5.1.2).
lifeCycleInfo	Attribute, association role	If in an application schema a property is considered to be part of the life-cycle information of a spatial object type, the property shall receive this stereotype.
version	Association role	If in an application schema an association role ends at a spatial object type, this stereotype denotes that the value of the property is meant to be a specific version of the spatial object, not the spatial object in general.

5.2 Application schema GE

5.2.1 Description

5.2.1.1. Narrative description and UML Overview

The core of the data specification for Geology, Geology Main, is based closely on GeoSciML (*http://www.geosciml.org/*). GeoSciML has been developed by an international geological working

group under the auspices of the Commission for Geoscience Information (CGI) of the International Union of Geological Sciences (IUGS). The scope of GeoSciML is primarily the information shown on geological maps, along with boreholes, and for the INSPIRE data specification a sub-set of GeoSciML has been used. Geomorphology is not covered by GeoSciML and this has been added to GeologyMain.

The hydrogeology part of the data specification is based in part on GroundwaterML (*http://ngwd-bdnes.cits.rncan.gc.ca/service/api_ngwds/en/gwml.html*) developed by the Geological Survey of Canada, but extended to meet European requirements in particular the Water Framework Directive.

The third principal component of the INSPIRE Geology specification covers geophysics. This is not based on any external domain specific standard, but draws on ISO19156 on Observations & Measurements.

A characteristic of geologic data is that many properties have a large number of permissible values. These are generally held in vocabularies and referenced by applications. It is considered that putting these large codelists in the model is not appropriate so they have been listed in Appendix E.

For each of the three main components of the data specification a core has been identified which it is considered should be the minimum requirement for the INSPIRE process. For Geology and Geophysics there is, in addition, an extension application schema to enable fuller interoperability.

The GeologyCore application schema is shown in Figure 1.

GeologicFeature is an abstract class including GeologicUnits (bodies of rock of some type), GeologicStructures, and GeomorphologicFeatures. In the INSPIRE specification the only type of GeologicStructure being considered are ShearDispacementStructures, which include faults. GeomorphologicFeatures are landforms, but they can have an association to an underlying GeologicUnit. GeomorphologicFeatures are sub-divided into natural and anthropogenic. A deformed GeologicUnit may have an association to a defining GeologicStructure.

GeologicFeatures can be considered as description classes which have an association to MappedFeatures which provide the spatial representation for the GeologicFeature. A MappedFeature obtains its geometry from GM_Object. A GeologicFeature can be associated with several MappedFeatures, for example for maps at different scales or 3D models. GeologicFeatures also have an association to GeologicEvent which provides both the age of the GeologicFeature, the event process, and the environment in which the event took place. All ages are considered the age of some event.

The final component of the mandatory core is Borehole with an association to BoreholeCollar to provide the location of the start point of the borehole.

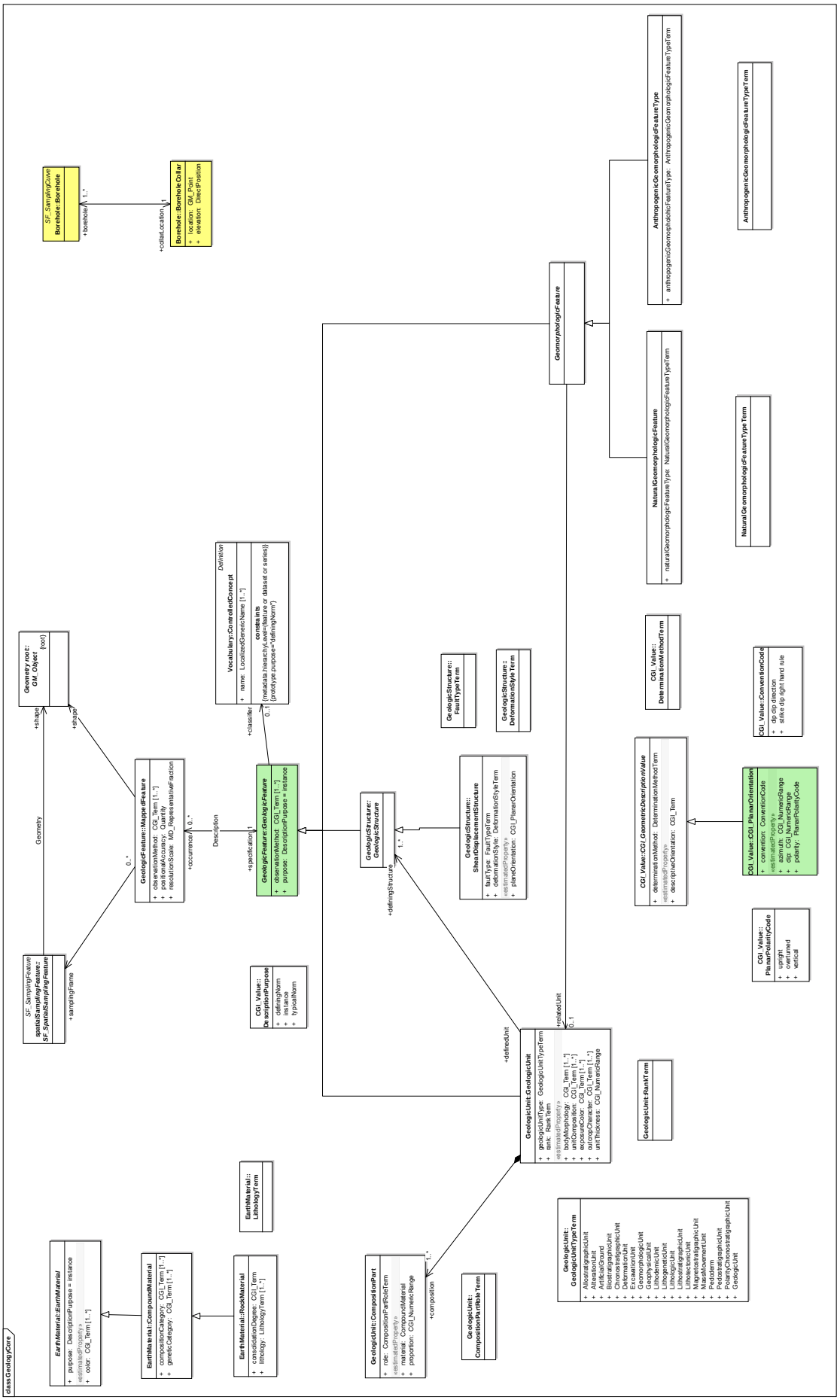

class GeologyCore
SF_SamplingCore
Borehole::Borehole
Borehole::BoreholeCollar
+ location: GM_Point
+ elevation: DirectPosition
+borehole
+collarLocation
Geometry root:
GM_Object
(root)
+shape
+shape
Vocabulary::ControlledConcept
Definition
constraints
+ name: LocalizedGenericName [1..*]
{metadata.hierarchyLevel=(feature or dataset or series)}
{prototype.purpose="definingNorm"}
+classifier
0..1
GeologicFeature::MappedFeature
+ observationMethod: CGI_Term [1..*]
+ positionalAccuracy: Quantity
+ resolutionScale: MD_RepresentativeFraction
+occurrence
0..*
Description
GeologicFeature::GeologicFeature
+ observationMethod: CGI_Term [1..*]
+ purpose: DescriptionPurpose = instance
+specification
1
Geometry
0..*
SF_SamplingFeature
spatialSamplingFeature:
SF_SpatialSamplingFeature
+samplingFrame
CGI Value::
DescriptionPurpose
+ definingNorm
+ instance
+ typicalNorm
GeologicStructure::
GeologicStructure
1..*
+definingStructure
GeologicStructure::
FaultTypeTerm
GeologicStructure::
DeformationStyleTerm
GeologicStructure::
ShearDisplacementStructure
+ faultType: FaultTypeTerm
+ deformationStyle: DeformationStyleTerm
«estimatedProperty»
+ planeOrientation: CGI_PlanarOrientation
GeomorphologicFeature
AnthropogenicGeomorphologicFeatureType
+ anthropogenicGeomorphologicFeatureType: AnthropogenicGeomorphologicFeatureTypeTerm
AnthropogenicGeomorphologicFeatureTypeTerm
NaturalGeomorphologicFeature
+ naturalGeomorphologicFeatureType: NaturalGeomorphologicFeatureTypeTerm
NaturalGeomorphologicFeatureTypeTerm
CGI Value::
DeterminationMethodTerm
CGI Value::CGI_GeometricDescriptionValue
+ determinationMethod: DeterminationMethodTerm
«estimatedProperty»
+ descriptiveOrientation: CGI_Term
CGI Value::CGI_PlanarOrientation
+ convention: ConventionCode
«estimatedProperty»
+ azimuth: CGI_NumericRange
+ dip: CGI_NumericRange
+ polarity: PlanarPolarityCode
CGI Value::ConventionCode
+ dip direction
+ strike dip right hand rule
CGI Value::
PlanarPolarityCode
+ upright
+ overturned
+ vertical
+definedUnit
+relatedUnit
0..1
GeologicUnit::GeologicUnit
+ geologicUnitType: GeologicUnitTypeTerm
+ rank: RankTerm
«estimatedProperty»
+ bodyMorphology: CGI_Term [1..*]
+ lithologicalComposition: CGI_Term [1..*]
+ exposureColor: CGI_Term [1..*]
+ outcropCharacter: CGI_Term [1..*]
+ unitThickness: CGI_NumericRange
GeologicUnit::RankTerm
GeologicUnit::
GeologicUnitTypeTerm
+ AllostratigraphicUnit
+ AttestationUnit
+ ArtificialGround
+ BiostratigraphicUnit
+ ChronostratigraphicUnit
+ DeformationUnit
+ ExcavationUnit
+ GeomorphologicUnit
+ GeochronologicUnit
+ LithodemicUnit
+ LithogeneticUnit
+ LithologicUnit
+ LithostratigraphicUnit
+ LithotectonicUnit
+ MagnetostratigraphicUnit
+ MassMovementUnit
+ PedologicUnit
+ PedostratigraphicUnit
+ PolarityChronostratigraphicUnit
+ GeologicUnit
GeologicUnit::CompositionPartRoleTerm
GeologicUnit::CompositionPart
+ role: CompositionPartRoleTerm
«estimatedProperty»
+ material: CompoundMaterial
+ proportion: CGI_NumericRange
+composition
1..*
EarthMaterial::EarthMaterial
+ purpose: DescriptionPurpose = instance
«estimatedProperty»
+ color: CGI_Term [1..*]
EarthMaterial::CompoundMaterial
+ compositionCategory: CGI_Term [1..*]
+ genericCategory: CGI_Term [1..*]
EarthMaterial::RockMaterial
+ consolidationDegree: CGI_Term
+ lithology: LithologyTerm [1..*]
EarthMaterial::
LithologyTerm

Figure 1 - UML class diagram : Geology Main mandatory core

The GeologyCore application schema uses the CGI_Value data type illustrated in Figure 2. A characteristic of many geological term properties is that they require a qualification of some type. Similarly numeric values are commonly an estimate requiring a statistical measure or variability measure attached to them. In addition both term and numeric property values commonly are recorded as a range (distinct from numeric variability). The abstract CGI_Value data type and its sub-types implement these requirements.

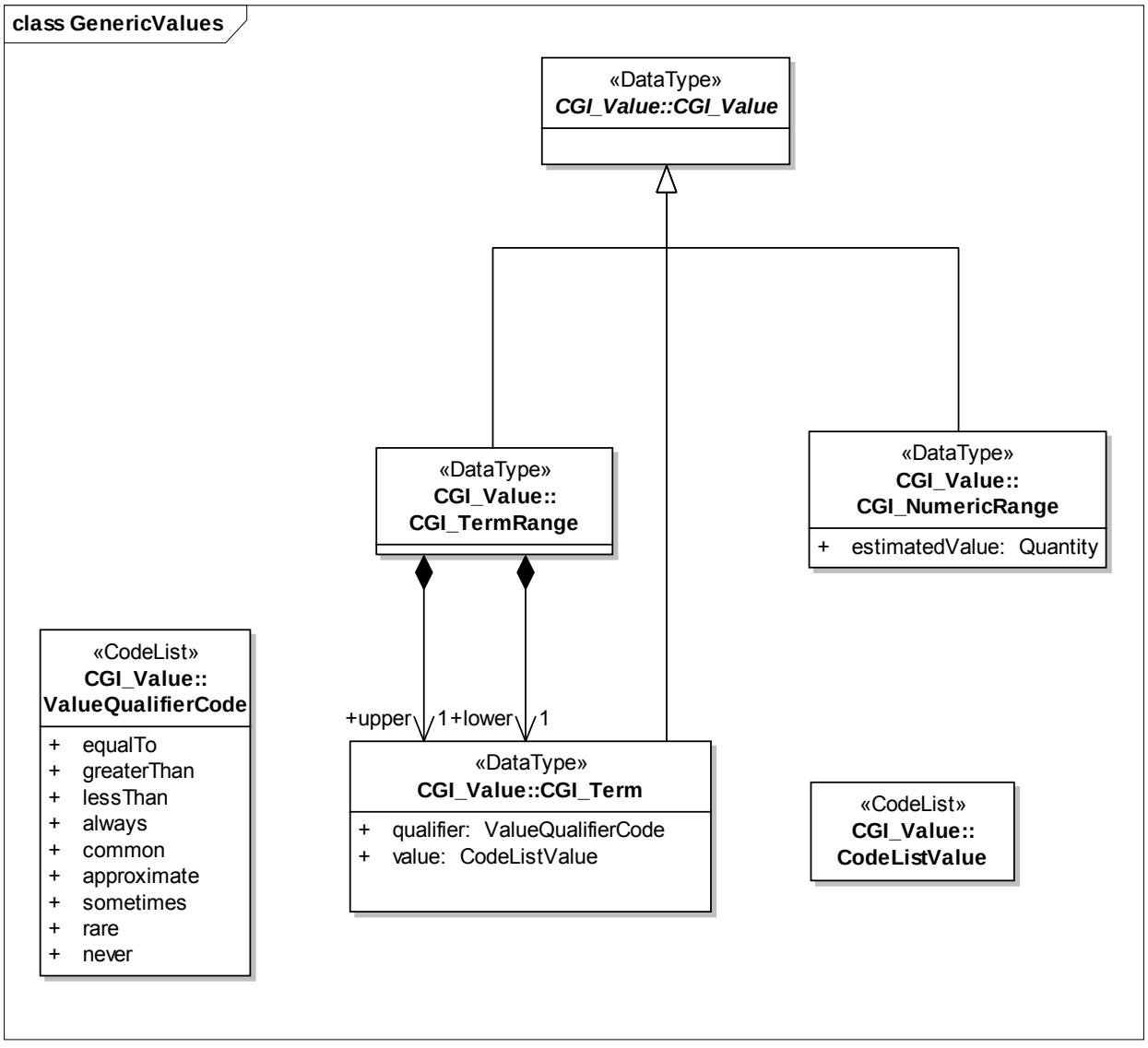


Figure 2 - UML class diagram: Generic values

The full GeologyMain specification allows the provision of more information about GeologicStructures, Boreholes, GeologicAge and PhysicalProperties.

The full specification of GeologicStructure is shown in Figure 3. This shows that in addition to that included in the mandatory core GeologicStructures have an association to DisplacementValue to record the total displacement that has taken place on the structure.

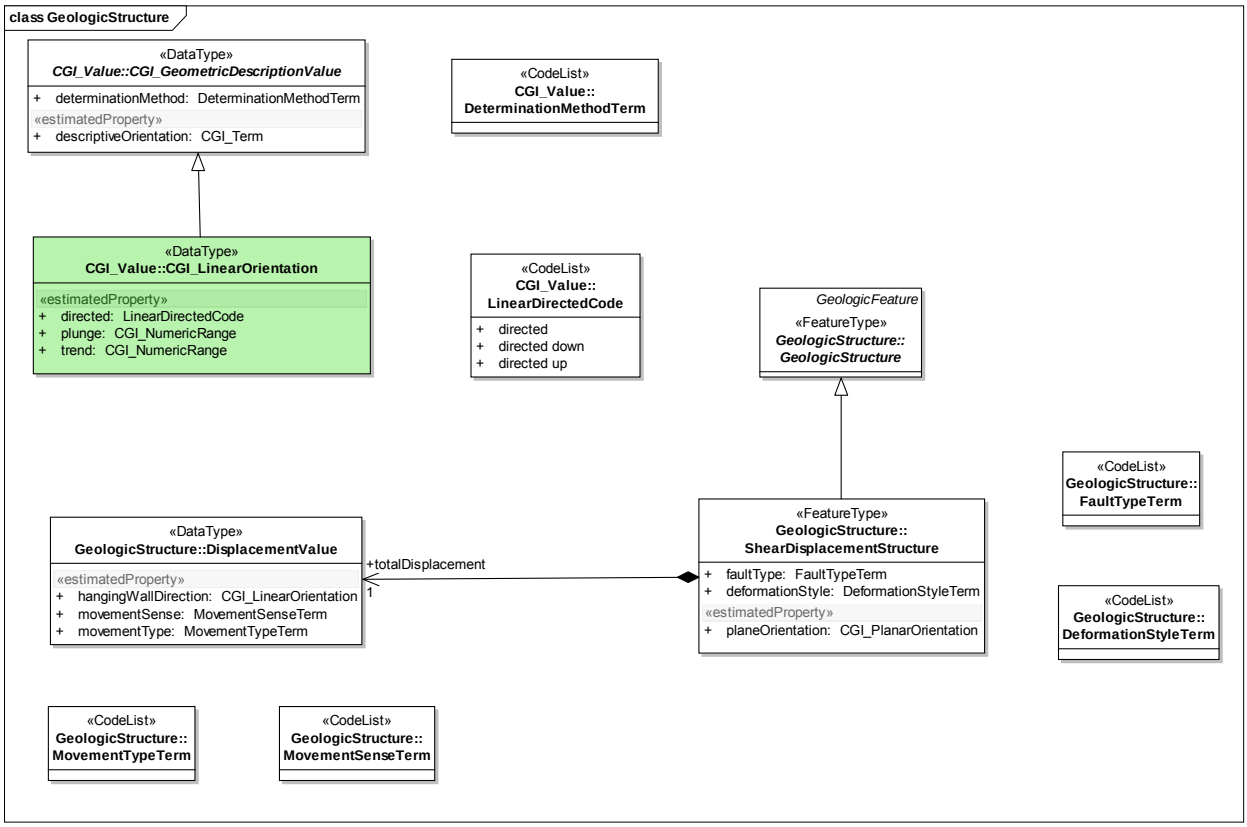


Figure 3- UML class diagram: GeologicStructure

The full application schema for Boreholes is shown in Figure 4. This shows that in addition to the classes included in the mandatory core there is an association from Borehole to BoreholeDetails, a datatype providing borehole specific metadata. ExtendedBoreholeDetails provides extra metadata for INSPIRE that is not included in GeoSciML. There is also an association to MappedInterval, a type of MappedFeature. MappedInterval is used to record information about an interval of a borehole log in the same way as an area on a geological map, and allows boreholes to be regarded as linear geological maps. Boreholes are modelled as types of SamplingCurve.

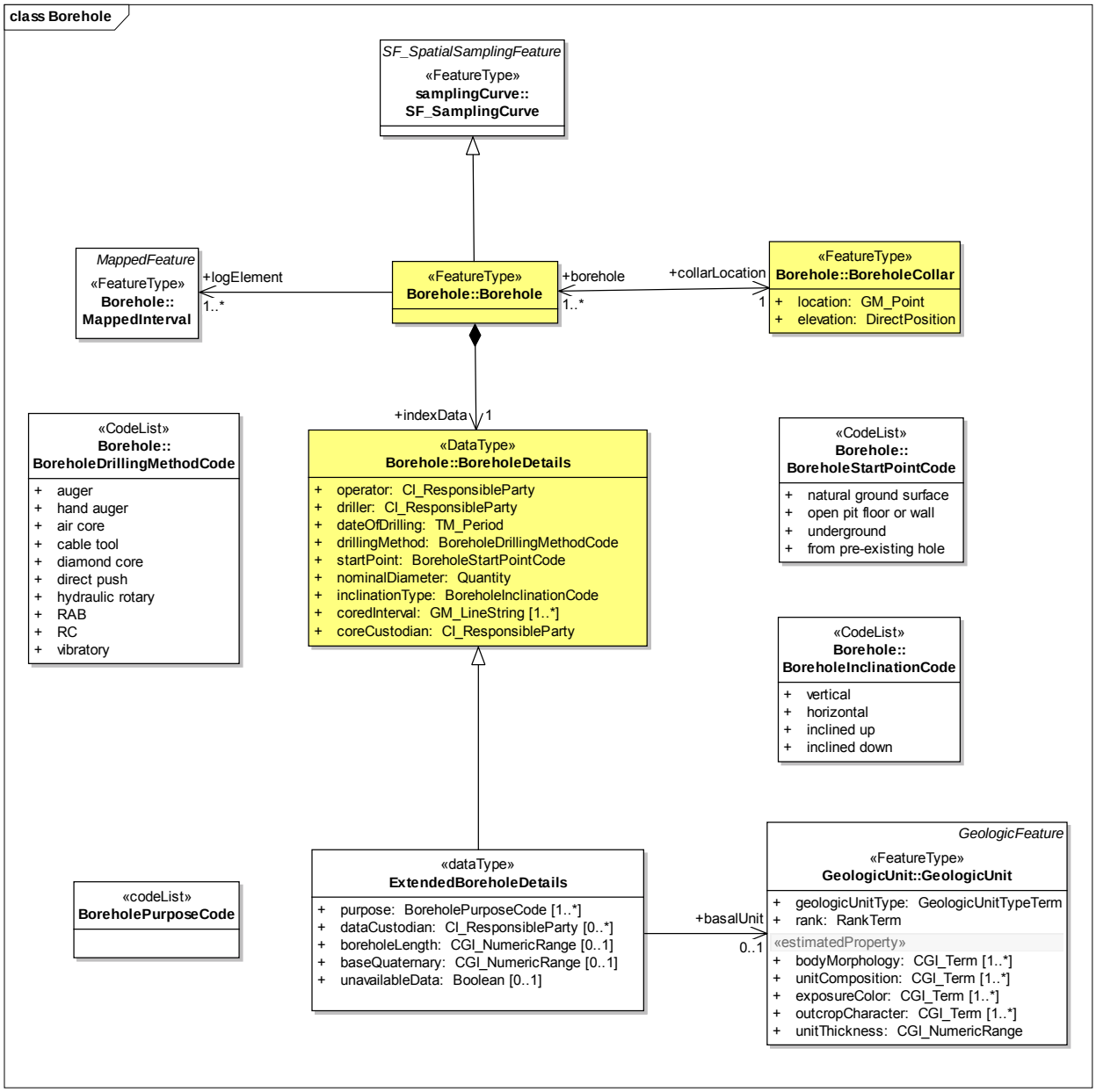


Figure 4 - UML class diagram: Borehole

In geology ages are recorded both numerically and in terms of geochronological eras, and the GeologicEvent feature allows for both methods to be used in recording the age of any GeologicFeature as illustrated in Figure 5. The diagram also shows the GeochronologicalEra type used in GeologicEvent. Ages are commonly recorded as a range of time and the data type CGI_NumericAgeRange allows for both a single reporting age and older and younger bounding ages, all with an accuracy measure.

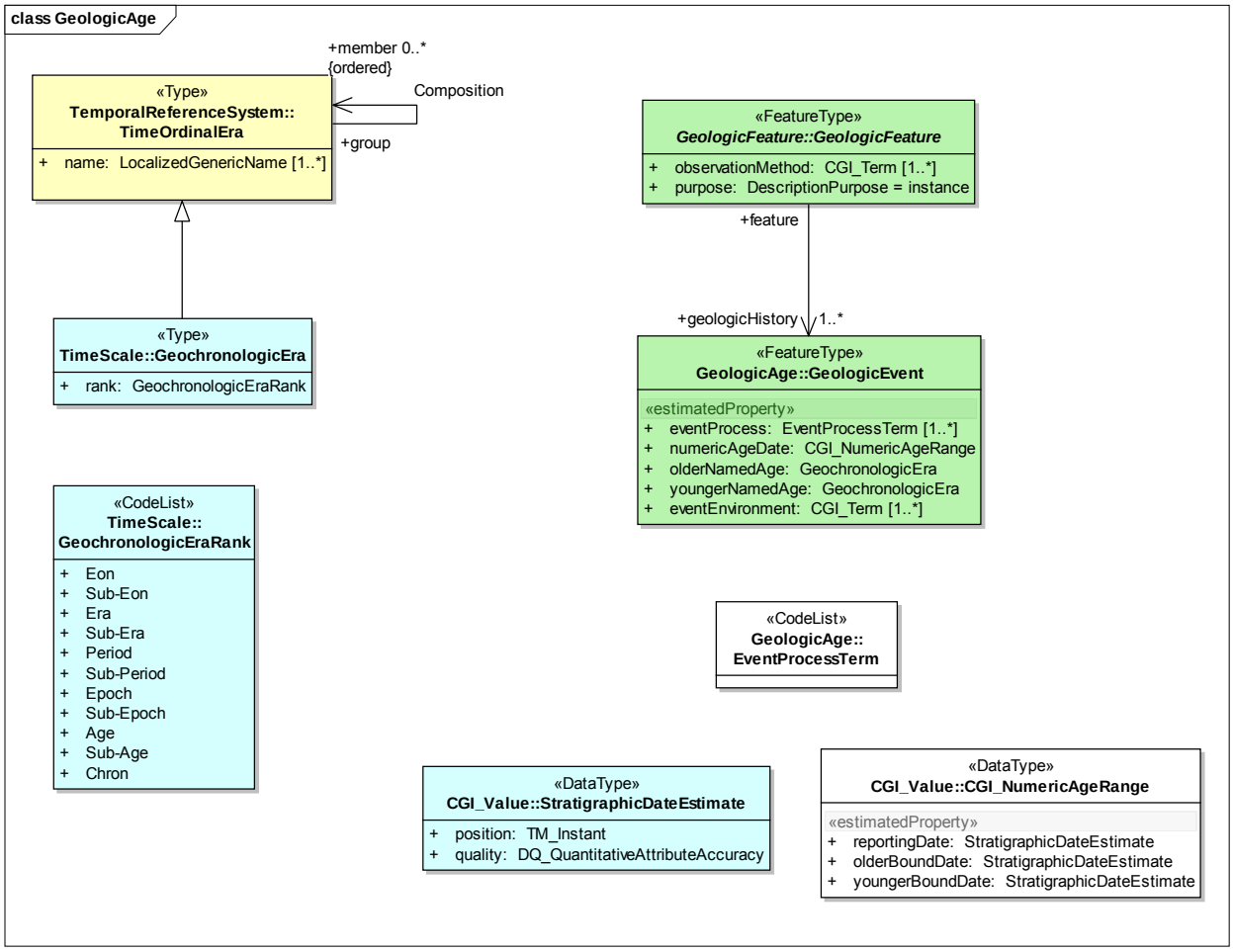


Figure 5 - UML class diagram: GeologicAge

The PhysicalDescription datatype is used as a means of recording the physical properties of GeologicUnits and ShearDisplacementStructures (Figure 6). It has two properties, propertyName and propertyMeasure, allowing the value of any physical property, as given in propertyName, to be recorded.

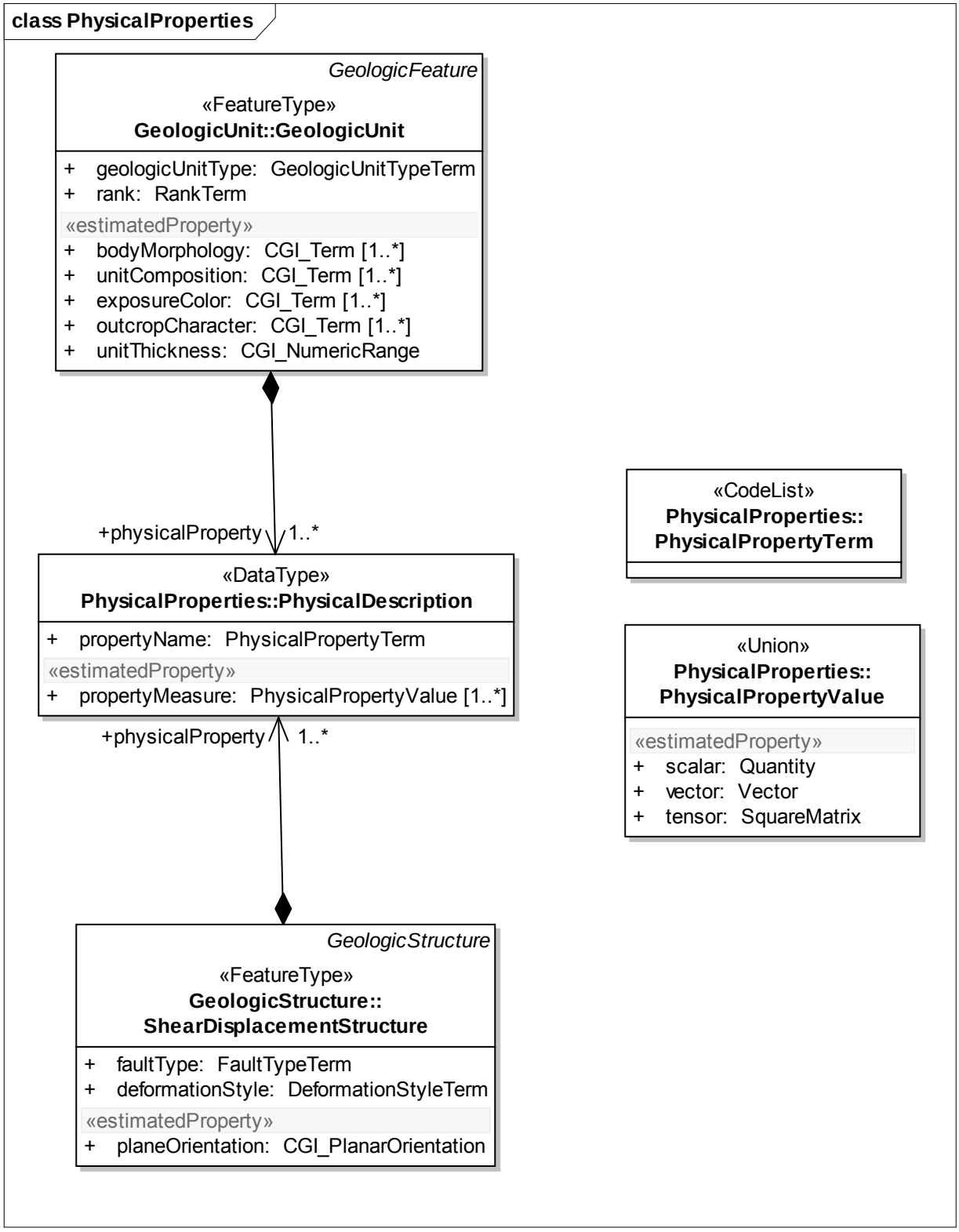


Figure 6 - UML class diagram: PhysicalDescription

The second component of the specification concerns geophysics which, like geology, is divided into a core and extension application schema. The core specification is concerned with providing geometry and metadata and covers measurements, models, seismics, and surveys as shown in Figures 7 – 10.

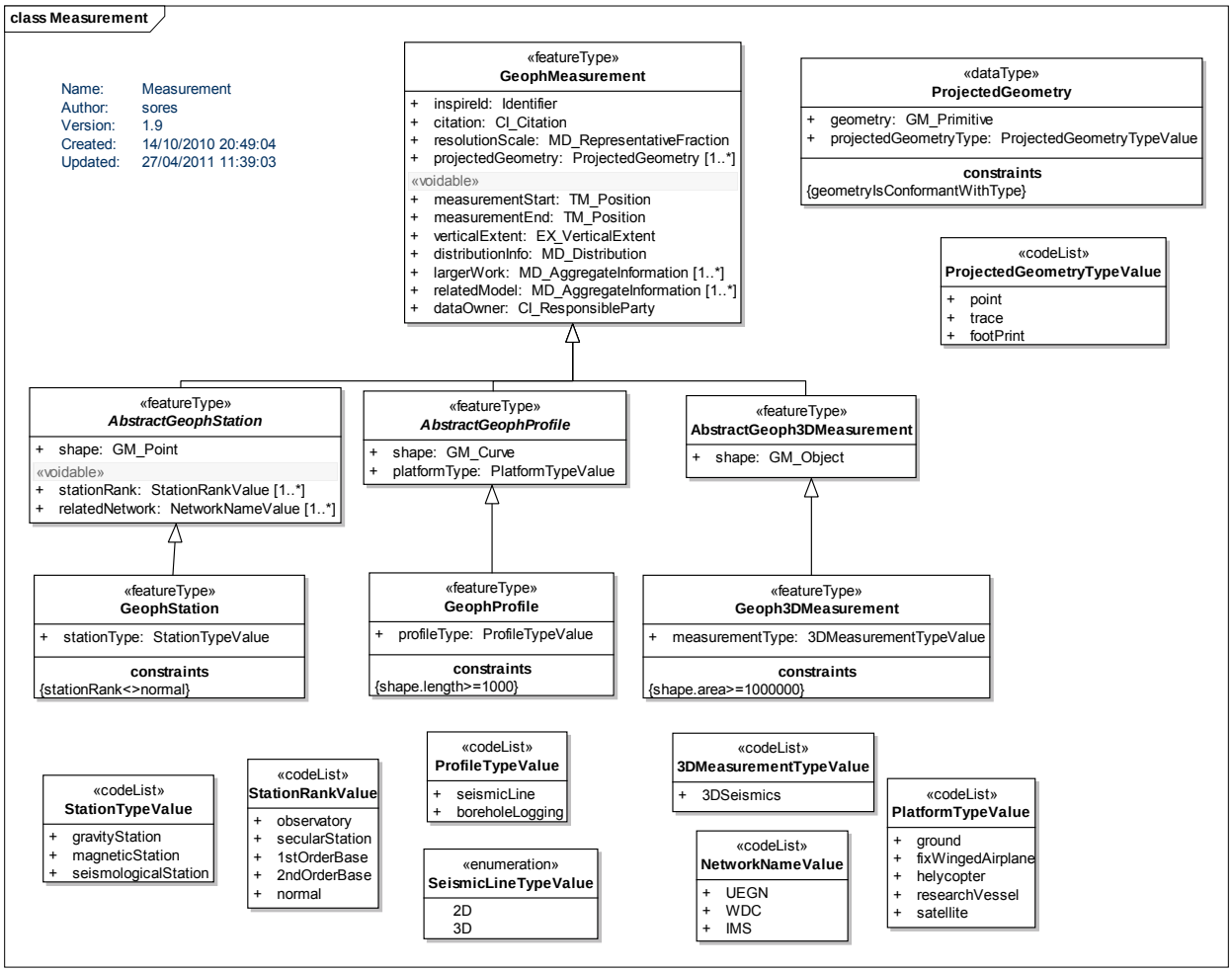


Figure 1 - UML class diagram: Geophysical measurements

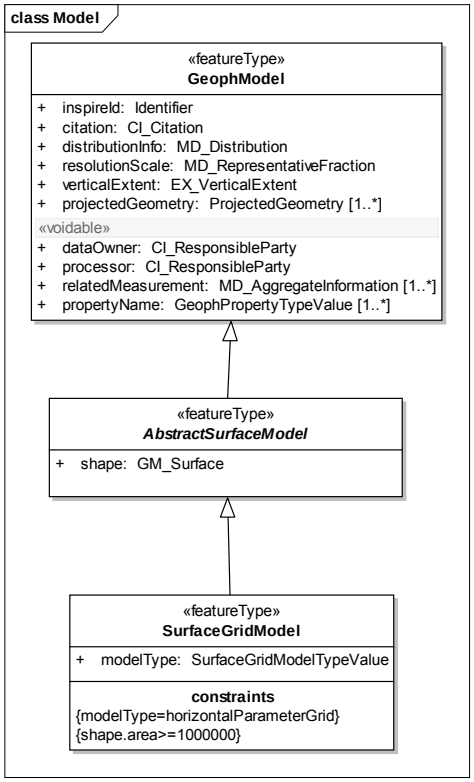


Figure 2 - UML class diagram: Geophysical models

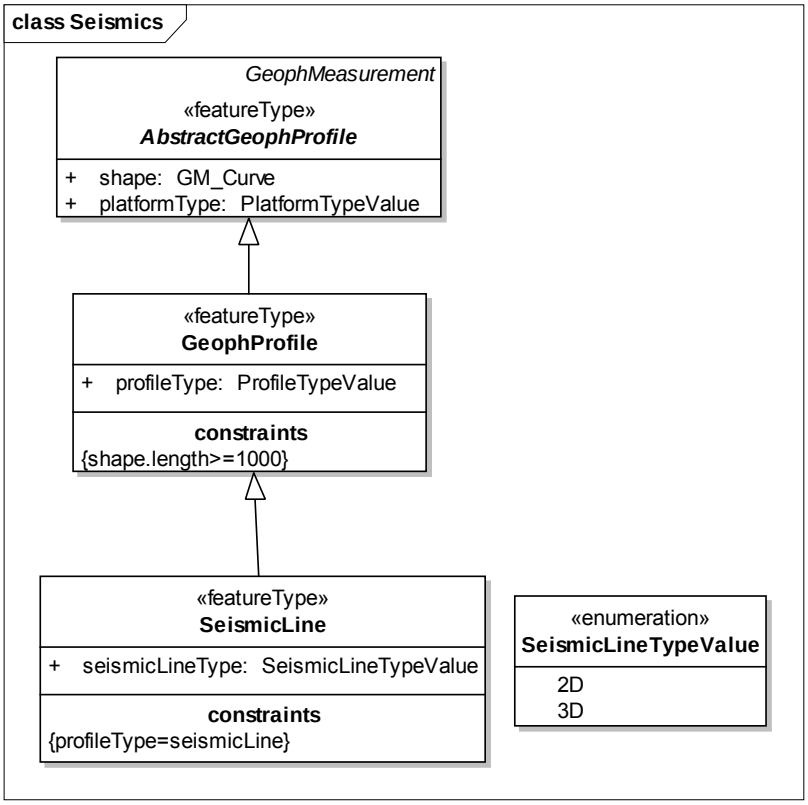


Figure 9 - UML class diagram: Seismics

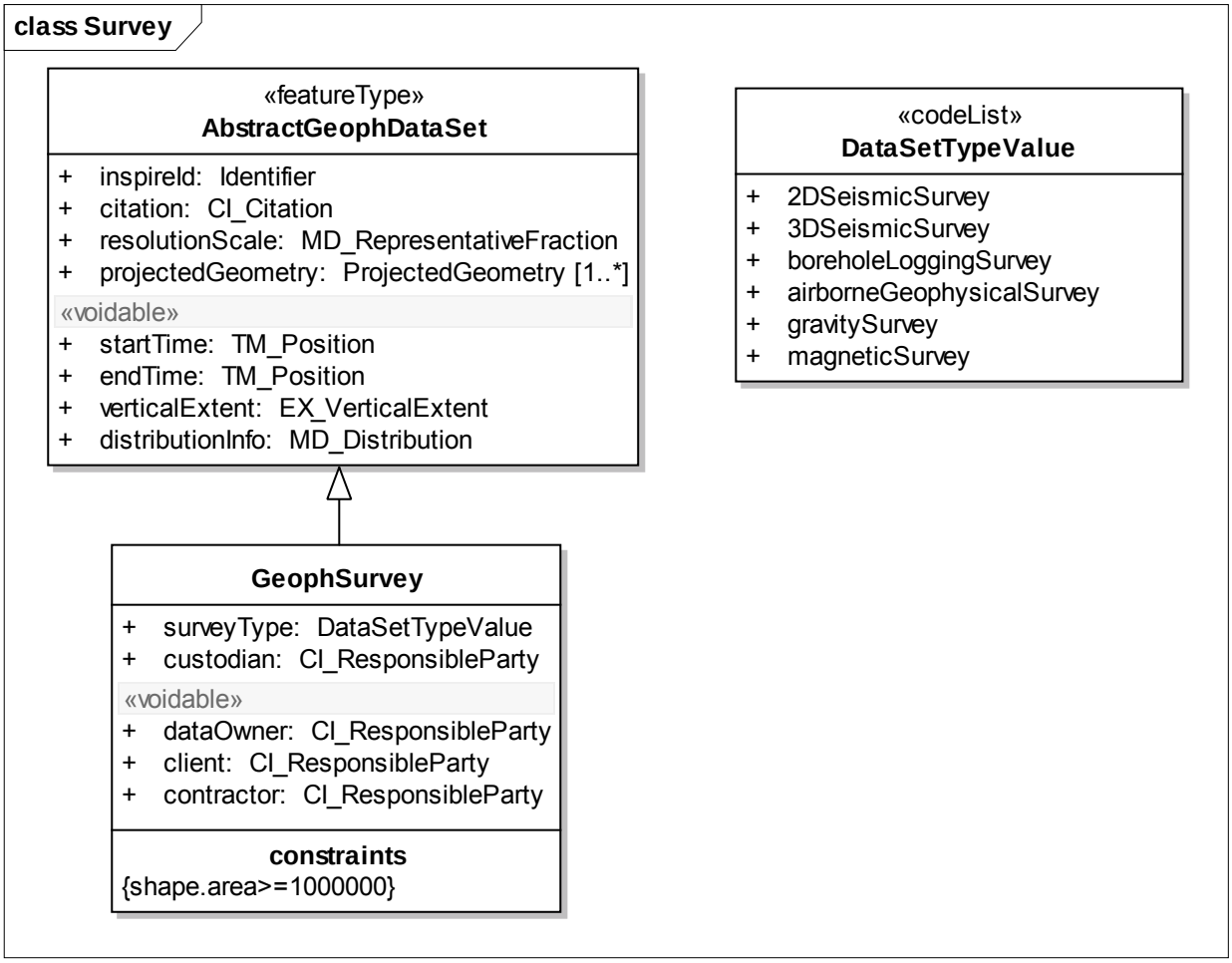


Figure 10 - UML class diagram: Geophysical surveys

The extended geophysics application schema draws on the Observations & Measurements standard to extend the core geophysics application schema with further metadata as well as measurement information as shown in figures 11 – 18.

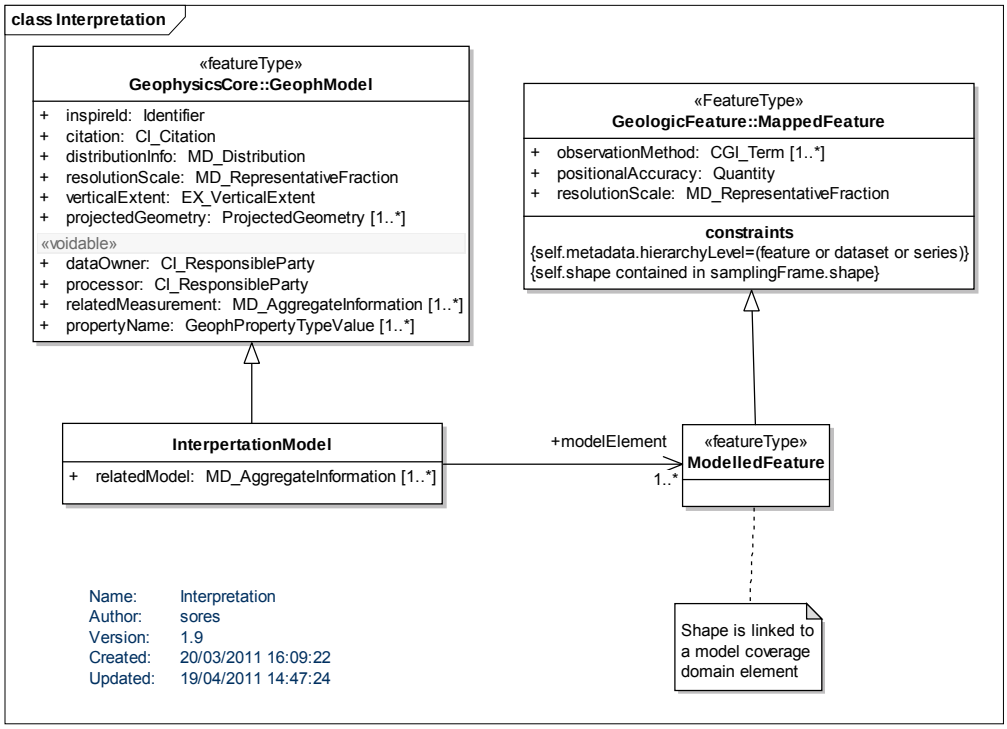


Figure 11 - UML class diagram: Interpretation

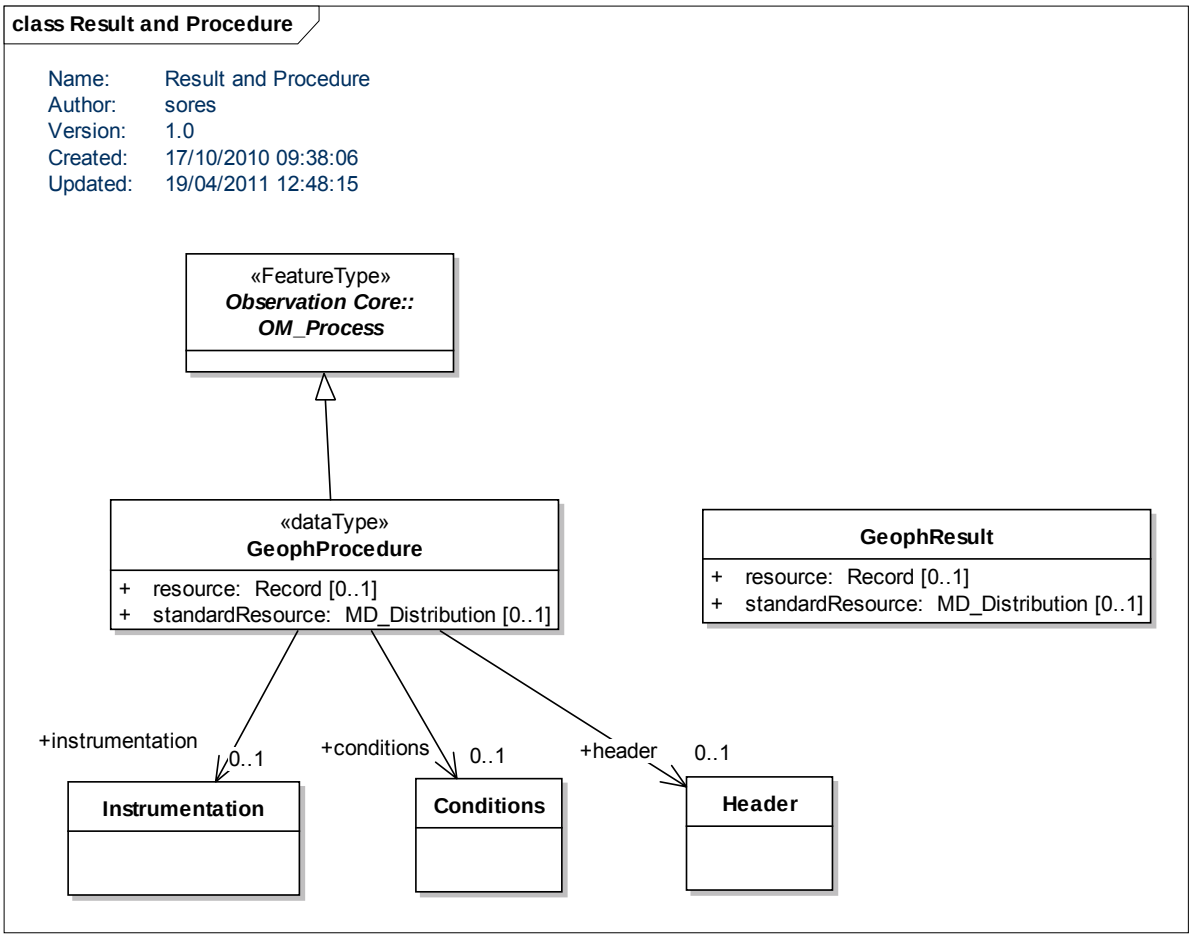


Figure 12 - UML class diagram: Results and procedures

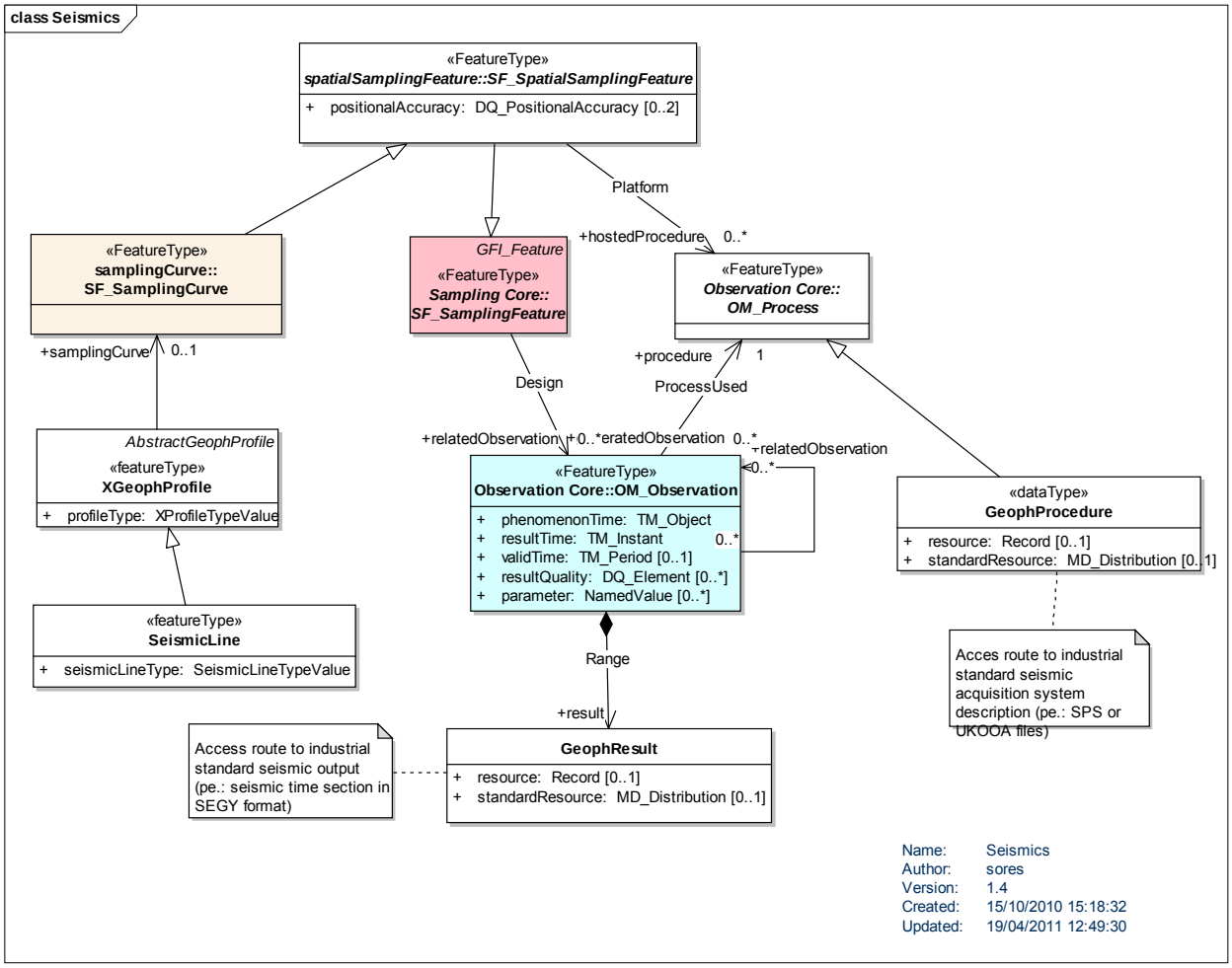


Figure 13 - UML class diagram: Seismics (full)

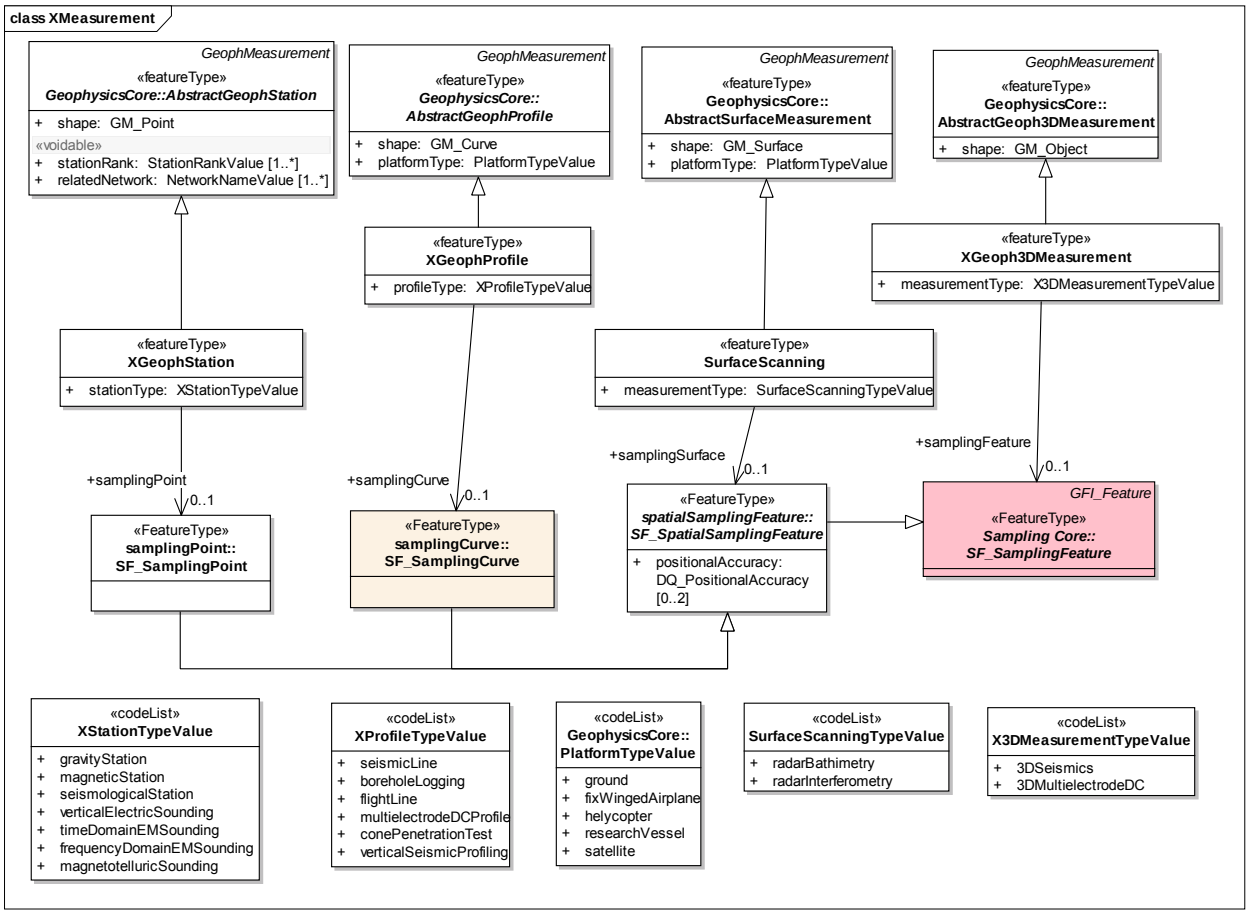


Figure 14 - UML class diagram: Measurement (full)

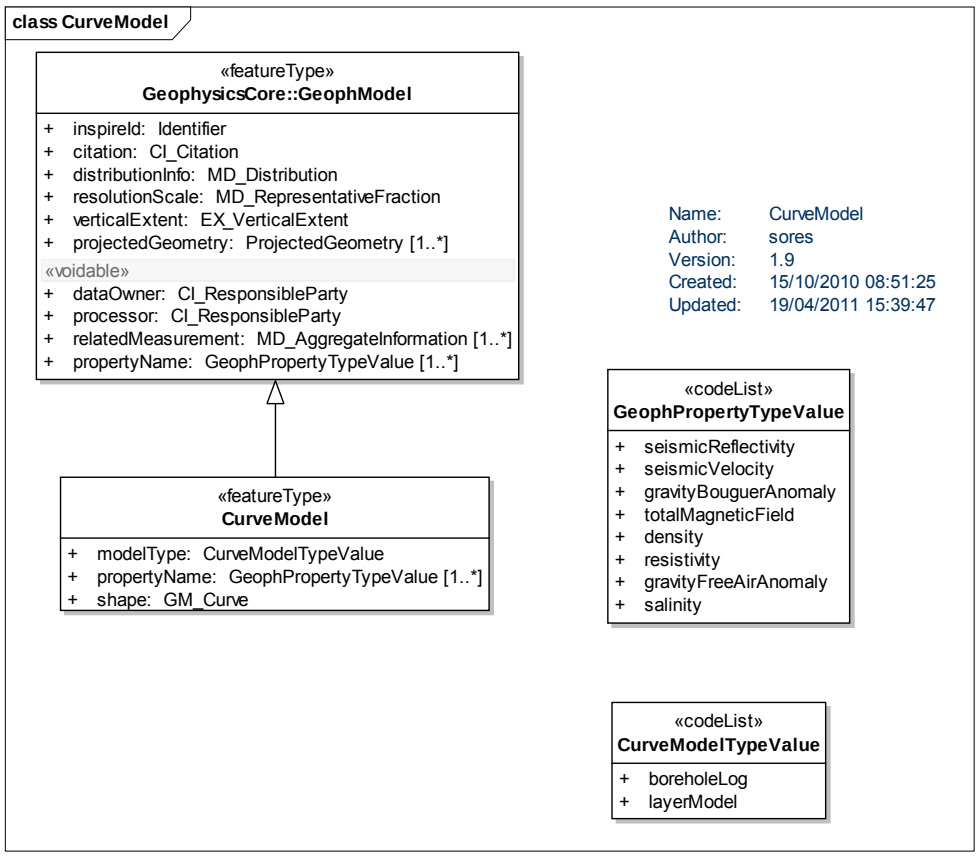


Figure 15 - UML class diagram: Curve models

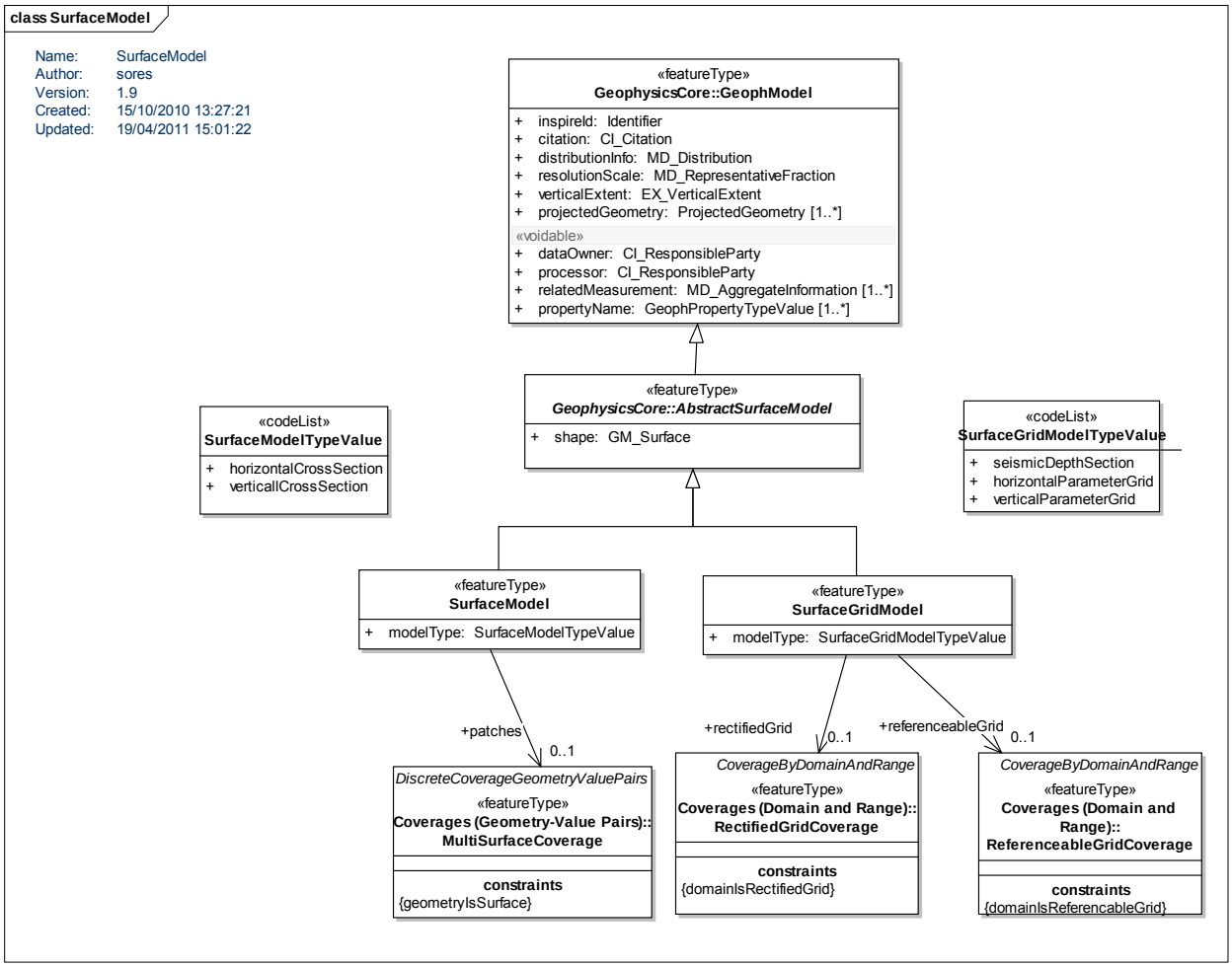


Figure 16 - UML class diagram: Surface models

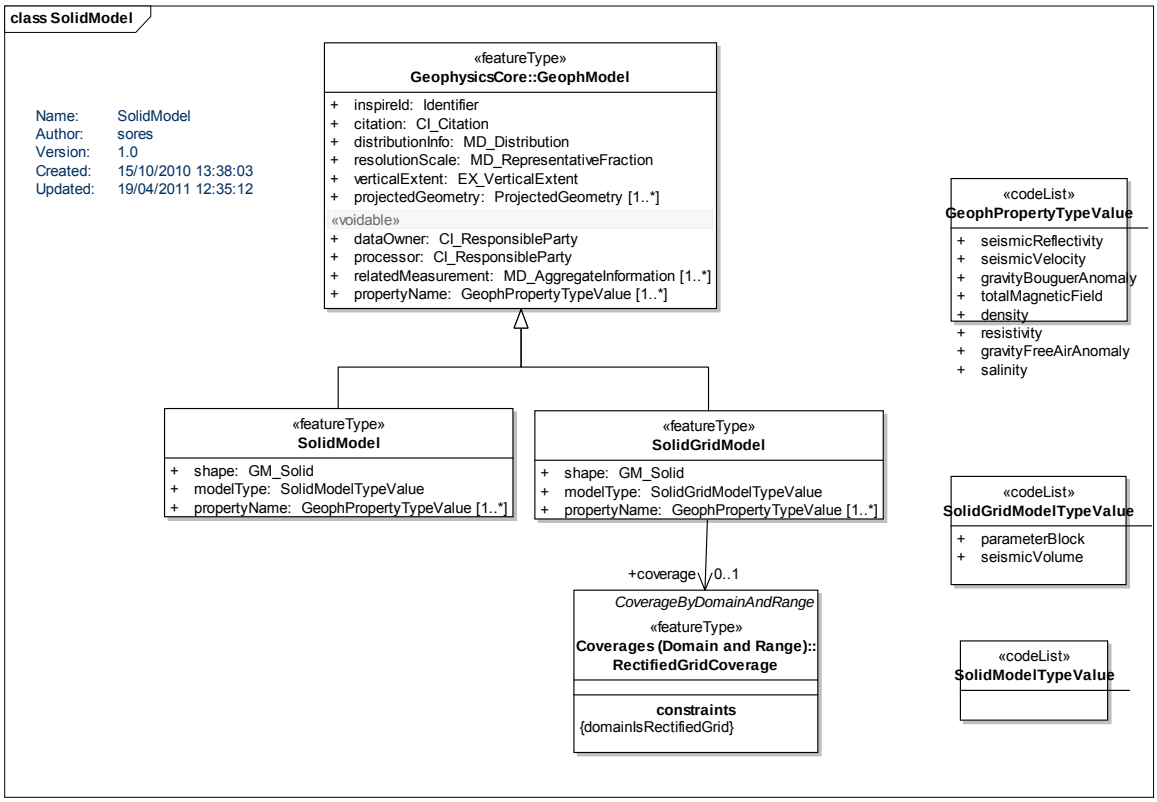


Figure 17 - UML class diagram: Solid models

The hydrogeological model is concerned with modelling the hydrogeological system and its components, as well as Water Wells and hydrogeological monitoring facilities. Figure 18 is a high level diagram of the overall hydrogeological system.

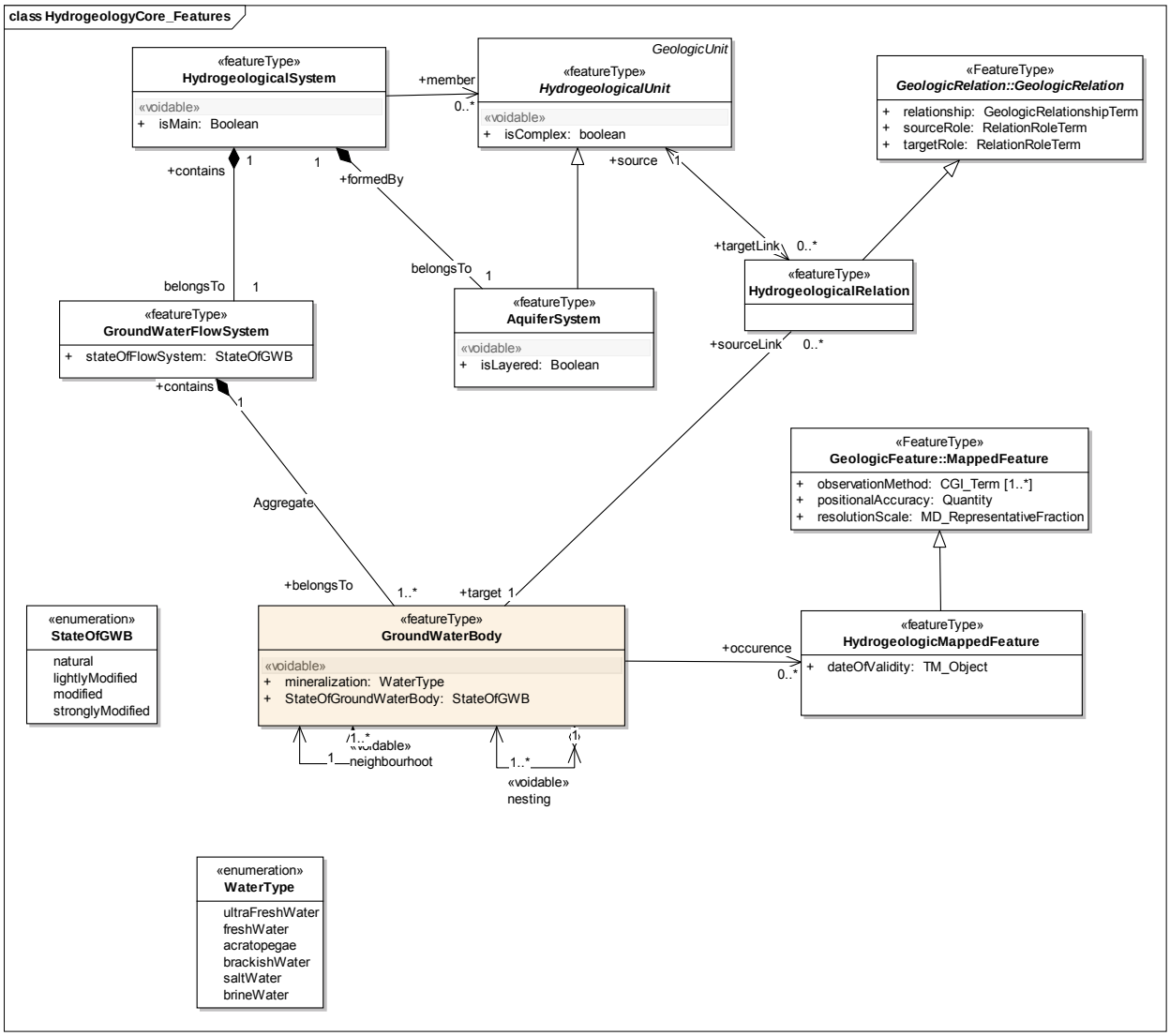


Figure 18 - UML class diagram: Hydrogeological system

HydrogeologicalUnits are modelled as a type of GeologicUnit, in which the delimiting properties are hydrogeological properties of the rock. The types of HydrogeologicalUnit and their relationships are shown in Figure 19.

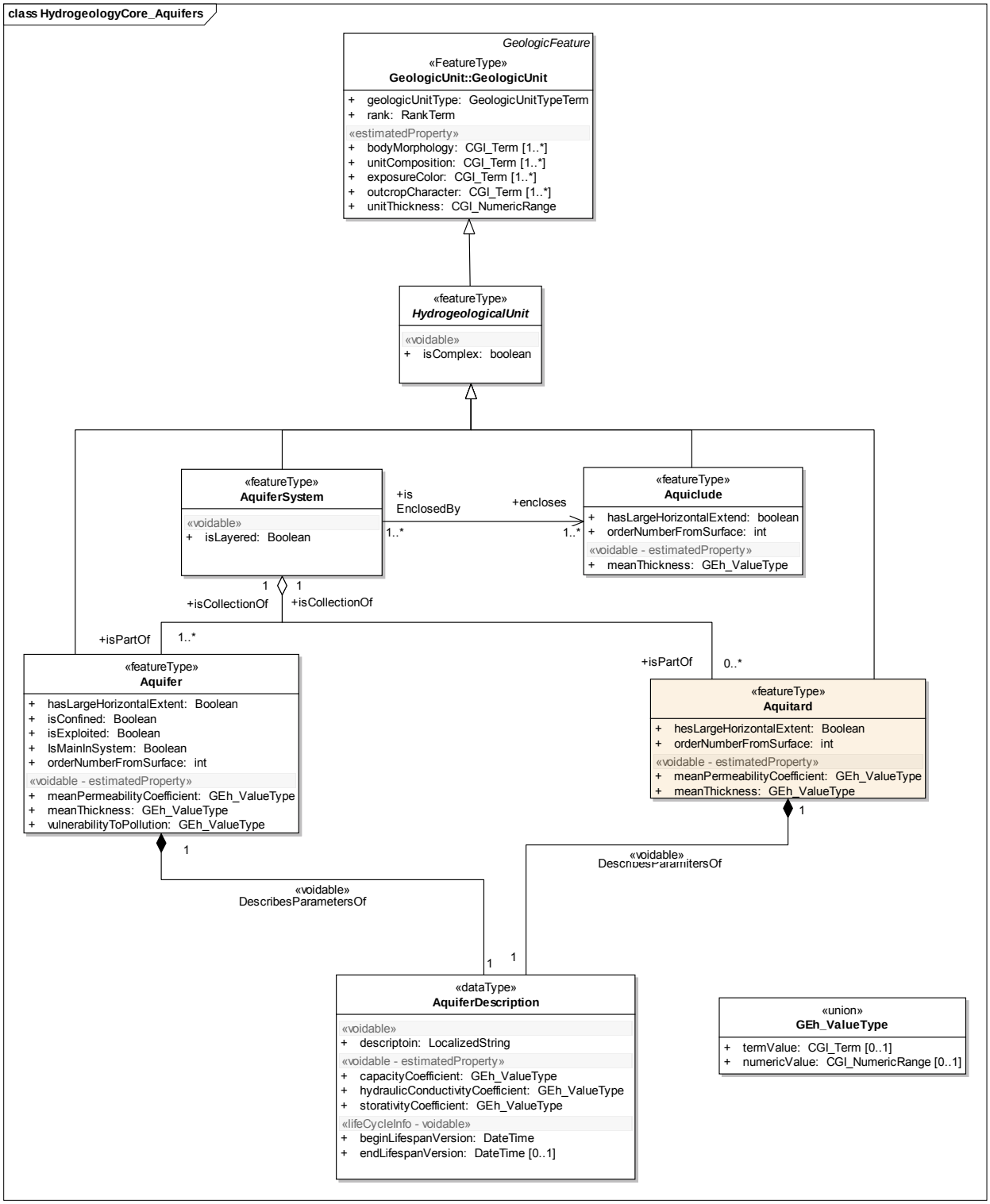


Figure 19 - UML class diagram: Hydrogeological Units

As well as the hydrogeological system the application schema describes WaterWells along with their relationship to Boreholes and Groundwater Monitoring. Also included are SpringOrSeep and VanishingPoint, inherited from the Annex I hydrography specification, which are modelled as a type of HydrogeologicalObjectNatural. These features are all shown in Figure 20.

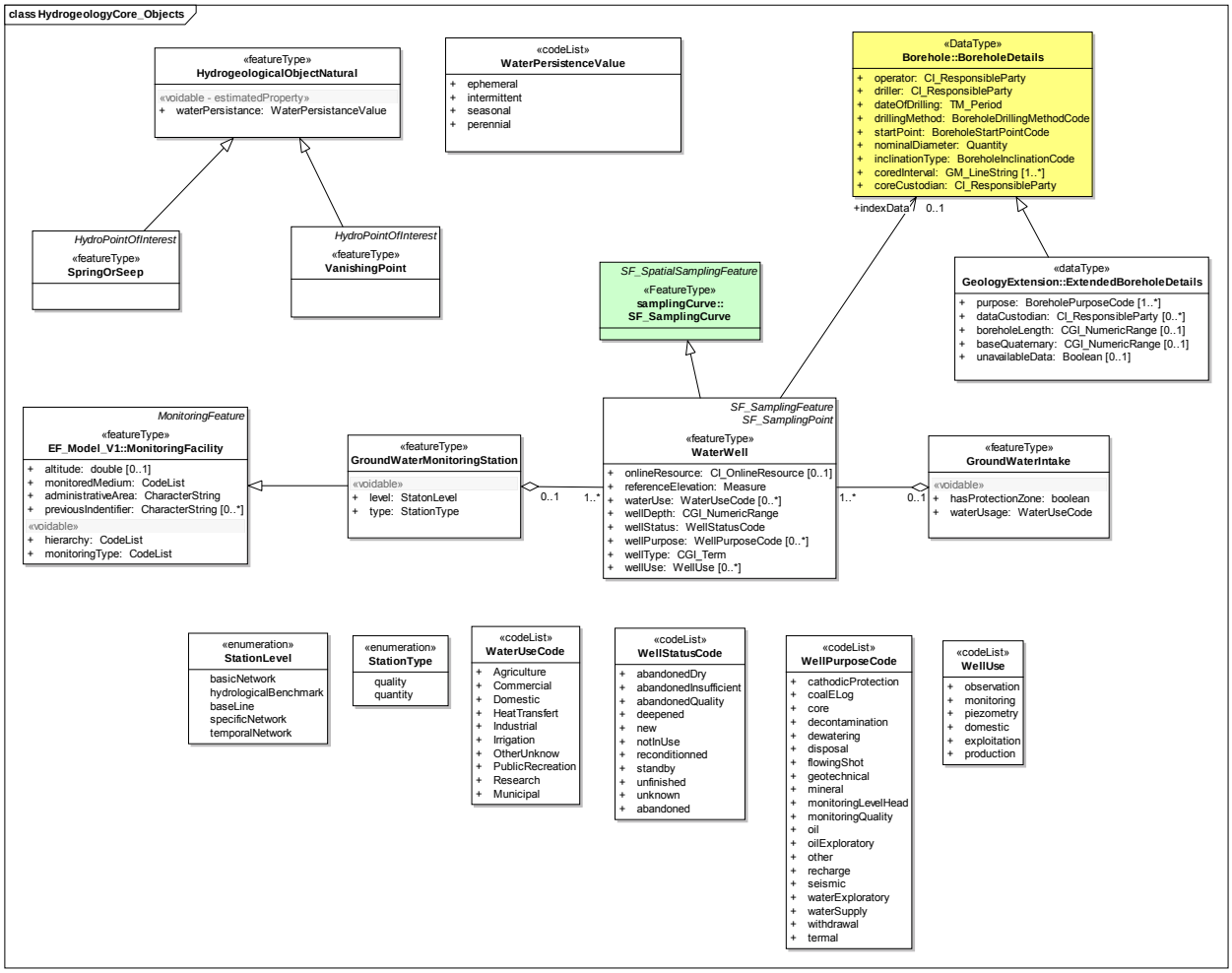


Figure 20 - UML class diagram: Water Wells and Hydrogeological Objects

5.2.1.2. Consistency between spatial data sets

The observation location is specified by its coordinates.

5.2.2 Feature catalogue

Table 3 - Feature catalogue metadata

Feature catalogue name	INSPIRE feature catalogue GeologyCore
Scope	GeologyCore
Version number	0.1
Version date	2010-10-27
Definition source	INSPIRE data specification GeologyCore

Table 4 - Types defined in the feature catalogue

Type	Package	Stereotypes	Section
AnthropogenicGeomorphologicFeatureType	GeologyCore	«featureType»	5.2.2.1.1
AnthropogenicGeomorphologicFeatureTypeTerm	GeologyCore	«codeList»	5.2.2.2.1
GeomorphologicFeature	GeologyCore	«featureType»	5.2.2.1.2
NaturalGeomorphologicFeature	GeologyCore	«featureType»	5.2.2.1.3
NaturalGeomorphologicFeatureTypeTerm	GeologyCore	«codeList»	5.2.2.2.2

5.2.2.1. Spatial object types

5.2.2.1.1. AnthropogenicGeomorphologicFeatureType

AnthropogenicGeomorphologicFeatureType	
Subtype of:	GeomorphologicFeature
Status:	Proposed
Stereotypes:	«featureType»
Attribute: anthropogenicGeomorpholohicFeatureType	
Value type:	AnthropogenicGeomorphologicFeatureTypeTerm
Multiplicity:	1

5.2.2.1.2. GeomorphologicFeature

GeomorphologicFeature (abstract)	
Subtype of:	GeologicFeature
Definition:	A geomorphological feature is a linear or areal landform. It may be associated with an underlying GeologicUnit
Status:	Proposed
Stereotypes:	«featureType»
Association role: relatedUnit	
Value type:	GeologicUnit
Multiplicity:	0..1

5.2.2.1.3. NaturalGeomorphologicFeature

NaturalGeomorphologicFeature	
Subtype of:	GeomorphologicFeature
Status:	Proposed
Stereotypes:	«featureType»
Attribute: naturalGeomorphologicFeatureType	
Value type:	NaturalGeomorphologicFeatureTypeTerm
Multiplicity:	1

5.2.2.2. Code lists

5.2.2.2.1. AnthropogenicGeomorphologicFeatureTypeTerm

AnthropogenicGeomorphologicFeatureTypeTerm	
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.

5.2.2.2.2. NaturalGeomorphologicFeatureTypeTerm

NaturalGeomorphologicFeatureTypeTerm	
Definition:	The types of natural geomorphological feature
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.

5.2.2.3. Imported types (informative)

This section lists definitions for feature types, data types and enumerations and code lists that are defined in other application schemas. The section is purely informative and should help the reader understand the feature catalogue presented in the previous sections. For the normative documentation of these types, see the given references.

5.2.2.3.1. GeologicFeature

GeologicFeature (abstract)

GeologicFeature (abstract)	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::GeoSciML-Core::GeologicFeature [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.2.3.2. GeologicUnit

GeologicUnit	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::GeoSciML-Core::GeologicUnit [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.3 Feature catalogue

Table 3 - Feature catalogue metadata

Feature catalogue name	INSPIRE feature catalogue GeologyExtension
Scope	GeologyExtension
Version number	0.1
Version date	2010-10-27
Definition source	INSPIRE data specification GeologyExtension

Table 4 - Types defined in the feature catalogue

Type	Package	Stereotypes	Section
BoreholePurposeCode	GeologyExtension	«codeList»	5.2.2.2.1
ExtendedBoreholeDetails	GeologyExtension	«dataType»	5.2.2.1.1

5.2.3.1. Spatial object types

5.2.3.2. Data types

5.2.3.2.1. ExtendedBoreholeDetails

ExtendedBoreholeDetails	
Subtype of:	BoreholeDetails
Definition:	Extended borehole specific index (or metadata) information
Status:	Proposed
Stereotypes:	«dataType»
Attribute: baseQuaternary	
Value type:	CGI_NumericRange
Multiplicity:	0..1
Attribute: boreholeLength	
Value type:	CGI_NumericRange
Definition:	The total length of the borehole
Multiplicity:	0..1
Attribute: dataCustodian	
Value type:	CI_ResponsibleParty
Definition:	Organisation that is custodian of data derived from the borehole
Multiplicity:	0..*
Attribute: purpose	
Value type:	BoreholePurposeCode

ExtendedBoreholeDetails	
Definition:	The purpose for which the borehole was drilled eg site investigation, resource exploration etc
Multiplicity:	1..*
Attribute: unavailableData	
Value type:	Boolean
Multiplicity:	0..1
Association role: basalUnit	
Value type:	GeologicUnit
Multiplicity:	0..1

5.2.3.3. Code lists

5.2.3.3.1. BoreholePurposeCode

BoreholePurposeCode	
Definition:	The purpose for which a borehole was drilled eg site investigation, resource exploration etc
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.

5.2.3.4. Imported types (informative)

This section lists definitions for feature types, data types and enumerations and code lists that are defined in other application schemas. The section is purely informative and should help the reader understand the feature catalogue presented in the previous sections. For the normative documentation of these types, see the given references.

5.2.3.4.1. Boolean

Boolean	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19103 Conceptual Schema Language::ISO 19103:2005 Schema Language::Basic Types::Primitive::Truth [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.3.4.2. BoreholeDetails

BoreholeDetails	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::Borehole [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.3.4.3. CGI_NumericRange

CGI_NumericRange	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::CGI_Utilities::CGI_Value [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.3.4.4. CI_ResponsibleParty

CI_ResponsibleParty	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Citation and responsible party information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.3.4.5. GeologicUnit

GeologicUnit	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::GeoSciML-Core::GeologicUnit [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4 Feature catalogue

Table 3 - Feature catalogue metadata

Feature catalogue name	INSPIRE feature catalogue GeophysicsCore
Scope	GeophysicsCore
Version number	0.1
Version date	2010-10-27
Definition source	INSPIRE data specification GeophysicsCore

Table 4 - Types defined in the feature catalogue

Type	Package	Stereotypes	Section
3DMeasurementTypeValue	GeophysicsCore	«codeList»	5.2.2.4.1
AbstractGeoph3DMeasurement	GeophysicsCore	«featureType»	5.2.2.1.1
AbstractGeophDataSet	GeophysicsCore	«featureType»	5.2.2.1.2
AbstractGeophProfile	GeophysicsCore	«featureType»	5.2.2.1.3
AbstractGeophStation	GeophysicsCore	«featureType»	5.2.2.1.4
AbstractSurfaceMeasurement	GeophysicsCore	«featureType»	5.2.2.1.5
AbstractSurfaceModel	GeophysicsCore	«featureType»	5.2.2.1.6
DataSetTypeValue	GeophysicsCore	«codeList»	5.2.2.4.2
Geoph3DMeasurement	GeophysicsCore	«featureType»	5.2.2.1.7
GeophMeasurement	GeophysicsCore	«featureType»	5.2.2.1.8
GeophModel	GeophysicsCore	«featureType»	5.2.2.1.9
GeophProfile	GeophysicsCore	«featureType»	5.2.2.1.10
GeophStation	GeophysicsCore	«featureType»	5.2.2.1.11
NetworkNameValue	GeophysicsCore	«codeList»	5.2.2.4.3
PlatformTypeValue	GeophysicsCore	«codeList»	5.2.2.4.4
ProfileTypeValue	GeophysicsCore	«codeList»	5.2.2.4.5
ProjectedGeometry	GeophysicsCore	«dataType»	5.2.2.2.1
ProjectedGeometryTypeValue	GeophysicsCore	«codeList»	5.2.2.4.6
SeismicLine	GeophysicsCore	«featureType»	5.2.2.1.12
SeismicLineTypeValue	GeophysicsCore	«enumeration»	5.2.2.3.1
StationRankValue	GeophysicsCore	«codeList»	5.2.2.4.7
StationTypeValue	GeophysicsCore	«codeList»	5.2.2.4.8
SurfaceGridModel	GeophysicsCore	«featureType»	5.2.2.1.13

5.2.4.1. Spatial object types

5.2.4.1.1. AbstractGeoph3DMeasurement

AbstractGeoph3DMeasurement	
Subtype of:	GeophMeasurement
Definition:	Abstract class for 3D Geophysical measurements
Description:	

AbstractGeoph3DMeasurement	
Status:	Proposed
Stereotypes:	«featureType»
Attribute: shape	
Value type:	GM_Object
Multiplicity:	1

5.2.4.1.2. AbstractGeophDataSet

AbstractGeophDataSet	
Definition:	Generic feature type for geophysical datasets.
Description:	
Status:	Proposed
Stereotypes:	«featureType»
Attribute: citation	
Value type:	CI_Citation
Multiplicity:	1
Attribute: distributionInfo	
Value type:	MD_Distribution
Definition:	Distribution metadata
Description:	Link to measured data access point
Multiplicity:	1
Stereotypes:	«voidable»
Attribute: endTime	
Value type:	TM_Position
Definition:	End of survey, campaign or project
Multiplicity:	1
Stereotypes:	«voidable»
Attribute: inspireId	
Value type:	Identifier
Definition:	External object identifier of the measurement.
Description:	NOTE An external object identifier is a unique object identifier published by the responsible body, which may be used by external applications to reference the spatial object. The identifier is an identifier of the spatial object, not an identifier of the real-world phenomenon.
Multiplicity:	1
Attribute: projectedGeometry	
Value type:	ProjectedGeometry
Multiplicity:	1..*
Attribute: resolutionScale	
Value type:	MD_RepresentativeFraction
Definition:	NOTE: this attribute type will be mapped to a temporary proxy for MD_RepresentativeFraction until support for GML3.2 is achieved. Reciprocal of equivalent scale of resolution for delineation of a feature's geometry. This is in contrast to positionAccuracy which is a measure of how well a feature is located relative to other features in the geographic reference system.
Multiplicity:	1
Attribute: startTime	

AbstractGeophDataSet

Value type:	TM_Position
Definition:	Start of survey, campaign or project
Multiplicity:	1
Stereotypes:	«voidable»

Attribute: verticalExtent

Value type:	EX_VerticalExtent
Definition:	Vertical extent of the sampling configuration
Description:	Geophysical measurements often have vertical extent. Example: A borehole logging measurement is usually displayed on maps as a point, but the sampling takes place in a vertical or inclined borehole
Multiplicity:	1
Stereotypes:	«voidable»

5.2.4.1.3. AbstractGeophProfile

AbstractGeophProfile (abstract)

Subtype of:	GeophMeasurement
Definition:	Geophysical measurement spatially referenced to a curve
Description:	Used to collect data along a curve. Examples: 2D seismic measurement, borehole logging, airborne geophysical flight line NOTE1. Processing results of geophProfiles are often surface coverages
Status:	Proposed
Stereotypes:	«featureType»

Attribute: platformType

Value type:	PlatformTypeValue
Multiplicity:	1

Attribute: shape

Value type:	GM_Curve
Multiplicity:	1

5.2.4.1.4. AbstractGeophStation

AbstractGeophStation (abstract)

Subtype of:	GeophMeasurement
Definition:	Geophysical measurement spatially referenced to a single point location
Description:	Used to collect data at a single location. The source-sensor setup may be alongated or two dimensional, but the collected data is referenced to a single point. Example: Gravity station, Magnetic station NOTE 1. Processing results of geophStations are often curve coverages
Status:	Proposed
Stereotypes:	«featureType»

Attribute: relatedNetwork

Value type:	NetworkNameValue
Definition:	Name of a national or international observation network which the station belongs to, or which measured data is reported to.
Multiplicity:	1..*
Stereotypes:	«voidable»

Attribute: shape

AbstractGeophStation (abstract)

Value type: GM_Point
Multiplicity: 1

Attribute: stationRank

Value type: StationRankValue
Definition: Geophysical stations may be part of a hyerarchical system. Rank relates to the importance of a station
Multiplicity: 1..*
Stereotypes: «voidable»

5.2.4.1.5. AbstractSurfaceMeasurement

AbstractSurfaceMeasurement

Subtype of: GeophMeasurement
Definition: Abstract class for Geophysical measurements spatially referenced to a surface
Status: Proposed
Stereotypes: «featureType»

Attribute: platformType

Value type: PlatformTypeValue
Multiplicity: 1

Attribute: shape

Value type: GM_Surface
Multiplicity: 1

5.2.4.1.6. AbstractSurfaceModel

AbstractSurfaceModel (abstract)

Subtype of: GeophModel
Definition: Abstract class for Surface models
Status: Proposed
Stereotypes: «featureType»

Attribute: shape

Value type: GM_Surface
Multiplicity: 1

5.2.4.1.7. Geoph3DMeasurement

Geoph3DMeasurement

Subtype of: AbstractGeoph3DMeasurement
Definition: 3D Geophysical measurement spatially referenced to a surface
Description: In the core model scope is restricted by the size od the data acquisition area.
Status: Proposed
Stereotypes: «featureType»

Attribute: measurementType

Value type: 3DMeasurementTypeValue
Multiplicity: 1

Constraint: shape.area>=1000000

Natural language: area is greater than 1 km2
OCL:

5.2.4.1.8. GeophMeasurement

GeophMeasurement

Definition:	Generic feature for geophysical measurements.
Description:	Geophysical measurements collect data outside or on the boundary of the observed spatial domain.
Status:	Proposed
Stereotypes:	«featureType»

Attribute: citation

Value type:	CI_Citation
Definition:	Citation of the model resource data
Description:	title, date of publication etc.
Multiplicity:	1

Attribute: dataOwner

Value type:	CI_ResponsibleParty
Definition:	Owner of the model
Description:	Ownership is usually inherited from campaign to measurement. If not, data owner may be defined for separate measurements.
Multiplicity:	1
Stereotypes:	«voidable»

Attribute: distributionInfo

Value type:	MD_Distribution
Definition:	Distribution metadata
Description:	Link to measured data access point
Multiplicity:	1
Stereotypes:	«voidable»

Attribute: inspireId

Value type:	Identifier
Definition:	External object identifier of the measurement.
Description:	NOTE An external object identifier is a unique object identifier published by the responsible body, which may be used by external applications to reference the spatial object. The identifier is an identifier of the spatial object, not an identifier of the real-world phenomenon.
Multiplicity:	1

Attribute: largerWork

Value type:	MD_AggregateInformation
Definition:	reference to a larger work, tipically a campaign or project
Multiplicity:	1..*
Stereotypes:	«voidable»

Attribute: measurementEnd

Value type:	TM_Position
Definition:	End of the sampling procedure
Multiplicity:	1
Stereotypes:	«voidable»

Attribute: measurementStart

Value type:	TM_Position
Definition:	Start of the sampling procedure
Multiplicity:	1
Stereotypes:	«voidable»

GeophMeasurement

Attribute: projectedGeometry

Value type: ProjectedGeometry
Multiplicity: 1..*

Attribute: relatedModel

Value type: MD_AggregateInformation
Definition: Reference to the geophysical model that was created from the measurement
Multiplicity: 1..*
Stereotypes: «voidable»

Attribute: resolutionScale

Value type: MD_RepresentativeFraction
Definition: NOTE: this attribute type will be mapped to a temporary proxy for MD_RepresentativeFraction until support for GML3.2 is achieved. Reciprocal of equivalent scale of resolution for delineation of a feature's geometry. This is in contrast to positionAccuracy which is a measure of how well a feature is located relative to other features in the geographic reference system.
Multiplicity: 1

Attribute: verticalExtent

Value type: EX_VerticalExtent
Definition: Vertical extent of the sampling configuration
Description: Geophysical measurements often have vertical extent. Example: A borehole logging measurement is usually displayed on maps as a point, but the sampling takes place in a vertical or inclined borehole
Multiplicity: 1
Stereotypes: «voidable»

5.2.4.1.9. GeophModel

GeophModel

Definition: Generic feature type for geophysical models
Description: Spatial distribution of physical properties. Usually it is the result of geophysical processing. It provides distribution of physical properties within the observed spatial domain.
Status: Proposed
Stereotypes: «featureType»

Attribute: citation

Value type: CI_Citation
Definition: Citation of the model resource data
Description: title, date of publication etc.
Multiplicity: 1

Attribute: dataOwner

Value type: CI_ResponsibleParty
Definition: Owner of the geophysical data
Multiplicity: 1
Stereotypes: «voidable»

Attribute: distributionInfo

Value type: MD_Distribution
Definition: Distribution metadata
Description: Link to measured data access point

GeophModel	
Multiplicity:	1
Attribute: inspireId	
Value type:	Identifier
Definition:	External object identifier of the model .
Description:	NOTE An external object identifier is a unique object identifier published by the responsible body, which may be used by external applications to reference the spatial object. The identifier is an identifier of the spatial object, not an identifier of the real-world phenomenon.
Multiplicity:	1
Attribute: processor	
Value type:	CI_ResponsibleParty
Definition:	Party responsible for the processing (creator of the model)
Multiplicity:	1
Stereotypes:	«voidable»
Attribute: projectedGeometry	
Value type:	ProjectedGeometry
Multiplicity:	1..*
Attribute: propertyName	
Value type:	GeophPropertyTypeValue
Definition:	Name of the physical property contained in the model
Description:	Models are coverages of physical properties.
Multiplicity:	1..*
Stereotypes:	«voidable»
Attribute: relatedMeasurement	
Value type:	MD_AggregateInformation
Definition:	Reference to the geophysical measurement that was used to create the model
Multiplicity:	1..*
Stereotypes:	«voidable»
Attribute: resolutionScale	
Value type:	MD_RepresentativeFraction
Definition:	NOTE: this attribute type will be mapped to a temporary proxy for MD_RepresentativeFraction until support for GML3.2 is achieved. Reciprocal of equivalent scale of resolution for delineation of a feature's geometry. This is in contrast to positionAccuracy which is a measure of how well a feature is located relative to other features in the geographic reference system.
Multiplicity:	1
Attribute: verticalExtent	
Value type:	EX_VerticalExtent
Definition:	Vertical extent of the model
Multiplicity:	1

5.2.4.1.10. GeophProfile

GeophProfile	
Subtype of:	AbstractGeophProfile
Definition:	Geophysical profile
Description:	In the core model scope is restricted by the length of the profile
Status:	Proposed

GeophProfile

Stereotypes: «featureType»

Attribute: profileType

Value type: ProfileTypeValue
Multiplicity: 1

Constraint: shape.length>=1000

Natural language: length is greater than 1000 m
OCL:

5.2.4.1.11. GeophStation

GeophStation

Subtype of: AbstractGeophStation
Definition: Geophysical station
Description: The core model is restricted to high rank geophysical stations.
Status: Proposed
Stereotypes: «featureType»

Attribute: stationType

Value type: StationTypeValue
Definition: Type of geophysical measurement
Description: provides access to the extended codelist
Multiplicity: 1

Constraint: stationRank<>normal

Natural language: stationRank is not normal
OCL:

5.2.4.1.12. SeismicLine

SeismicLine

Subtype of: GeophProfile
Status: Proposed
Stereotypes: «featureType»

Attribute: seismicLineType

Value type: SeismicLineTypeValue
Multiplicity: 1

Constraint: profileType=seismicLine

Natural language:

5.2.4.1.13. SurfaceGridModel

SurfaceGridModel

Subtype of: AbstractSurfaceModel
Status: Proposed
Stereotypes: «featureType»

Attribute: modelType

Value type: SurfaceGridModelTypeValue
Multiplicity: 1

Constraint: modelType=horizontalParameterGrid

SurfaceGridModel	
Natural language:	modelType is horizontalParameterGrid
OCL:	

Constraint: shape.area>=1000000	
Natural language:	Area is greater than 1 km2
OCL:	

5.2.4.2. Data types

5.2.4.2.1. ProjectedGeometry

ProjectedGeometry	
Status:	Proposed
Stereotypes:	«dataType»

Attribute: geometry	
Value type:	GM_Primitive
Multiplicity:	1

Attribute: projectedGeometryType	
Value type:	ProjectedGeometryTypeValue
Multiplicity:	1

Constraint: geometryIsConformantWithType	
Natural language:	if projectedGeoemtryType=point geoemtry is point if projectedGeoemtryType=trave geoemtry is curve if projectedGeoemtryType=footprint geoemtry is polygon
OCL:	

5.2.4.3. Enumerations

5.2.4.3.1. SeismicLineTypeValue

SeismicLineTypeValue	
Status:	Proposed
Stereotypes:	«enumeration»

Value: 2D

Value: 3D

5.2.4.4. Code lists

5.2.4.4.1. 3DMeasurementTypeValue

3DMeasurementTypeValue	
Definition:	Externally handled codelist of 3D geophysical measurement types.
Description:	To be developed. Provided items are examples.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.

Value: 3DSeismics

5.2.4.4.2. DataSetTypeValue

DataSetTypeValue	
Definition:	Types of most important geophysical datasets

DataSetTypeValue	
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: 2DSeismicSurvey	
Definition:	2D seismic survey
Value: 3DSeismicSurvey	
Definition:	3D seismic survey
Value: airborneGeophysicalSurvey	
Definition:	Airborne geophysical survey
Value: boreholeLoggingSurvey	
Definition:	Borehole logging survey
Value: gravitySurvey	
Definition:	Gravity survey
Value: magneticSurvey	
Definition:	Magnetic measurement survey

5.2.4.4.3. NetworkNameValue

NetworkNameValue	
Definition:	Name of geophysical network
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: IMS	
Definition:	IMS Seismological network
Value: UEGN	
Definition:	Station is part of the Unified European Gravity Network
Value: WDC	
Definition:	Station data is reported to World Data Center

5.2.4.4.4. PlatformTypeValue

PlatformTypeValue	
Definition:	Platform on which data acquisition was carried out
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: fixWingedAirplane	
Definition:	Measurement carried out from fix winged airplane
Value: ground	
Definition:	Ground based measurement
Value: helycopter	
Definition:	Measurement carried out from helycopter
Value: researchVessel	

PlatformTypeValue	
Definition:	Measurement carried out from a ship
Value: satellite	
Definition:	Measurement carried out from a satellite

5.2.4.4.5. ProfileTypeValue

ProfileTypeValue	
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: boreholeLogging	
Definition:	Geophysical measurement in a borehole
Value: seismicLine	
Definition:	Seismic measurement alon a line

5.2.4.4.6. ProjectedGeometryTypeValue

ProjectedGeometryTypeValue	
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: footPrint	
Definition:	object is represented by it's 2D bounding polygon
Value: point	
Definition:	object is represented by a reference point
Value: trace	
Definition:	object is represented as a curve on the surface

5.2.4.4.7. StationRankValue

StationRankValue	
Definition:	Rank of geophysical station
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: 1stOrderBase	
Definition:	Base station of higher importance
Value: 2ndOrderBase	
Definition:	Base station of lower importance
Value: normal	
Definition:	Ordinary survey station
Value: observatory	
Definition:	Permanent monitoring facility with continuous observation scedule.
Value: secularStation	
Definition:	Base station to observ long term time variations. Applied to magnetic stations.

5.2.4.4.8. StationTypeValue

StationTypeValue	
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: gravityStation	
Definition:	Gravity measurement station
Value: magneticStation	
Definition:	Magnetic measurement station
Value: seismologicalStation	
Definition:	Seismologic measurement station

5.2.4.5. Imported types (informative)

This section lists definitions for feature types, data types and enumerations and code lists that are defined in other application schemas. The section is purely informative and should help the reader understand the feature catalogue presented in the previous sections. For the normative documentation of these types, see the given references.

5.2.4.5.1. CI_Citation

CI_Citation	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Citation and responsible party information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.2. CI_ResponsibleParty

CI_ResponsibleParty	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Citation and responsible party information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.3. EX_VerticalExtent

EX_VerticalExtent	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Extent information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.4. GM_Curve

GM_Curve	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19107 Spatial Schema::ISO 19107:2003 Spatial Schema:: Geometry::Geometric primitive [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.5. GM_Object

GM_Object (abstract)	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19107 Spatial Schema::ISO 19107:2003 Spatial Schema:: Geometry::Geometry root [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.6. GM_Point

GM_Point	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19107 Spatial Schema::ISO 19107:2003 Spatial Schema:: Geometry::Geometric primitive [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.7. GM_Primitive

GM_Primitive (abstract)	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19107 Spatial Schema::ISO 19107:2003 Spatial Schema:: Geometry::Geometric primitive [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.8. GM_Surface

GM_Surface	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19107 Spatial Schema::ISO 19107:2003 Spatial Schema:: Geometry::Geometric primitive [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.9. GeophPropertyTypeValue

GeophPropertyTypeValue	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsOM [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	Externally handled codelist of geophysical property types.
Description:	To be developed. Provided items are examples.

5.2.4.5.10. Identifier

Identifier	
Package:	INSPIRE Consolidated UML Model::Generic Conceptual Model::Base Types [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	External unique object identifier published by the responsible body, which may be used by external applications to reference the spatial object.
Description:	NOTE1 External object identifiers are distinct from thematic object identifiers. NOTE 2 The voidable version identifier attribute is not part of the unique identifier of a spatial object and may be used to distinguish two versions of the same spatial object. NOTE 3 The unique identifier will not change during the life-time of a spatial object.

5.2.4.5.11. MD_AggregateInformation

MD_AggregateInformation	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Identification information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.12. MD_Distribution

MD_Distribution

MD_Distribution	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Distribution information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.13. MD_RepresentativeFraction

MD_RepresentativeFraction	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Identification information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.4.5.14. SurfaceGridModelTypeValue

SurfaceGridModelTypeValue	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsOM [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	Surface grid model types
Description:	To be developed. Provided items are examples.

5.2.4.5.15. TM_Position

TM_Position	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19108 Temporal schema::ISO 19108:2006 Temporal Schema::Temporal Reference System [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5 Feature catalogue

Table 3 - Feature catalogue metadata

Feature catalogue name	INSPIRE feature catalogue GeophysicsOM
Scope	GeophysicsOM
Version number	0.1
Version date	2010-10-27
Definition source	INSPIRE data specification GeophysicsOM

Table 4 - Types defined in the feature catalogue

Type	Package	Stereotypes	Section
Campaign	GeophysicsOM	«featureType»	5.2.2.1.1
CampaignType	GeophysicsOM	«enumeration»	5.2.2.3.1
CurveModel	GeophysicsOM	«featureType»	5.2.2.1.2
CurveModelTypeValue	GeophysicsOM	«codeList»	5.2.2.4.1
GeophProcedure	GeophysicsOM	«dataType»	5.2.2.2.1
GeophPropertyTypeValue	GeophysicsOM	«codeList»	5.2.2.4.2
ModelledFeature	GeophysicsOM	«featureType»	5.2.2.1.3
Project	GeophysicsOM	«featureType»	5.2.2.1.4
SeismicLine	GeophysicsOM	«featureType»	5.2.2.1.5
SolidGridModel	GeophysicsOM	«featureType»	5.2.2.1.6

Type	Package	Stereotypes	Section
SolidGridModelTypeValue	GeophysicsOM	«codeList»	5.2.2.4.3
SolidModel	GeophysicsOM	«featureType»	5.2.2.1.7
SolidModelTypeValue	GeophysicsOM	«codeList»	5.2.2.4.4
SurfaceGridModel	GeophysicsOM	«featureType»	5.2.2.1.8
SurfaceGridModelTypeValue	GeophysicsOM	«codeList»	5.2.2.4.5
SurfaceModel	GeophysicsOM	«featureType»	5.2.2.1.9
SurfaceModelTypeValue	GeophysicsOM	«codeList»	5.2.2.4.6
SurfaceScanning	GeophysicsOM	«featureType»	5.2.2.1.10
SurfaceScanningTypeValue	GeophysicsOM	«codeList»	5.2.2.4.7
X3DMeasurementTypeValue	GeophysicsOM	«codeList»	5.2.2.4.8
XDataSetTypeValue	GeophysicsOM	«codeList»	5.2.2.4.9
XGeoph3DMeasurement	GeophysicsOM	«featureType»	5.2.2.1.11
XGeophProfile	GeophysicsOM	«featureType»	5.2.2.1.12
XGeophStation	GeophysicsOM	«featureType»	5.2.2.1.13
XProfileTypeValue	GeophysicsOM	«codeList»	5.2.2.4.10
XStationTypeValue	GeophysicsOM	«codeList»	5.2.2.4.11

5.2.5.1. Spatial object types

5.2.5.1.1. Campaign

Campaign

Subtype of: AbstractGeophDataSet
Definition: Geophysical activity extending over a limited time range and limited area for producing geophysical measurements, processing results or models.
Description: Campaigns can be considered as parents of geophysical measurements or models. Children may refer to parents through the ISO MD_aggregateInformation element. Responsibilities defined for the campaing can be inherited by children.
Status: Proposed
Stereotypes: «featureType»

Attribute: campaignType

Value type: CampaignType
Multiplicity: 1

Attribute: client

Value type: CI_ResponsibleParty
Multiplicity: 1
Stereotypes: «voidable»

Attribute: contractor

Value type: CI_ResponsibleParty
Multiplicity: 1
Stereotypes: «voidable»

Attribute: custodian

Value type: CI_ResponsibleParty
Multiplicity: 1

Attribute: dataOwner

Value type: CI_ResponsibleParty
Definition: Owner of geophysical data created during the campaign.

Campaign

Multiplicity: 1
Stereotypes: «voidable»

Attribute: surveyType

Value type: XDataSetTypeValue
Multiplicity: 1
Stereotypes: «voidable»

Association role: project

Value type: Project
Multiplicity:

Constraint: objectSetType=campaign

Natural language:

5.2.5.1.2. CurveModel

CurveModel

Subtype of: GeophModel
Definition: Curve coverage of geophysical properties
Description: Distribution of geophysical properties along a curve. The extended model contains an association to the curve coverage Examples: layer model from 1D inversion, interpreted borehole log.

NOTE 1. Model data access may also be provided through distribution metadata
Status: Proposed
Stereotypes: «featureType»

Attribute: modelType

Value type: CurveModelTypeValue
Multiplicity: 1

Attribute: propertyName

Value type: GeophPropertyTypeValue
Multiplicity: 1..*

Attribute: shape

Value type: GM_Curve
Multiplicity: 1

5.2.5.1.3. ModelledFeature

ModelledFeature

Subtype of: MappedFeature
Definition: Element of an interpretation model. -- Gescription -- During interpretation underground bodies delineated by geophysical processing are identified as, or linked to geological objects. The shape of a modelledElement is linked to a geometry domain element of a coverage associated with the GeophModel. NOTE 1. Physical properties do not always respect geological boundaries, and for this reason geophysical units are not necessarily coincident with geological units. NOTE 2. The GeologicUnitTypeTerm related to a ModelledFeature can be "geophysicalUnit".
Status: Proposed
Stereotypes: «featureType»

5.2.5.1.4. Project

Project

Subtype of: AbstractGeophDataSet
Definition: Geophysical activity extending over a longer time range and larger area, containing any number of campaigns.
Description: In the hierarchy of geophysical data sets projects are parents of geophysical campaigns, and usually cover whole exploration programs.
Status: Proposed
Stereotypes: «featureType»

Attribute: principalInverstigator

Value type: CI_ResponsibleParty
Multiplicity: 1

Association role: campaign

Value type: Campaign
Multiplicity: 0..*

Association role: parentProject

Value type: Project
Multiplicity:

Constraint: objectSetType=project

Natural language:

5.2.5.1.5. SeismicLine

SeismicLine

Subtype of: XGeophProfile
Status: Proposed
Stereotypes: «featureType»

Attribute: seismicLineType

Value type: SeismicLineTypeValue
Multiplicity: 1

5.2.5.1.6. SolidGridModel

SolidGridModel

Subtype of: GeophModel
Definition: Solid grid coverage of geophysical properties
Description: 3D grid of different geophysical properties. The extended model contains an association to the coverage.
Examples are seismic volume, or 3D resistivity grid from DC tomography.

NOTE 1. Coverage data access may also be provided through distribution metadata.
Status: Proposed
Stereotypes: «featureType»

Attribute: modelType

Value type: SolidGridModelTypeValue
Multiplicity: 1

Attribute: propertyName

Value type: GeophPropertyTypeValue

SolidGridModel	
Multiplicity:	1..*
Attribute: shape	
Value type:	GM_Solid
Multiplicity:	1
Association role: coverage	
Value type:	RectifiedGridCoverage
Multiplicity:	0..1

5.2.5.1.7. SolidModel

SolidModel	
Subtype of:	GeophModel
Definition:	Solid coverage of geophysical properties
Description:	Collection of solids that represent rock bodies delineated by different geophysical properties. The extended model contains an association to the coverage. NOTE 1. Coverage data access may also be provided through distribution metadata .
Status:	Proposed
Stereotypes:	«featureType»
Attribute: modelType	
Value type:	SolidModelTypeValue
Multiplicity:	1
Attribute: propertyName	
Value type:	GeophPropertyTypeValue
Multiplicity:	1..*
Attribute: shape	
Value type:	GM_Solid
Multiplicity:	1

5.2.5.1.8. SurfaceGridModel

SurfaceGridModel	
Subtype of:	AbstractSurfaceModel
Definition:	Surface grid coverage of geophysical properties
Description:	Horizontal or vertical cross section with grids of different geophysical properties. The extended model contains an association to the surface grid coverage. Examples: seismic depth section, resistiviy section from 2D inversion. NOTE 1. Grids restricted to a plain surface can be modelled by rectifiedGridCoverage. If grid data is projected to a 3D surface, referenceableGridCoverage can be used. NOTE 2. Coverage data access may also be provided through distribution metadata.
Status:	Proposed
Stereotypes:	«featureType»
Attribute: modelType	
Value type:	SurfaceGridModelTypeValue
Multiplicity:	1

SurfaceGridModel	
Association role: rectifiedGrid	
Value type:	RectifiedGridCoverage
Multiplicity:	0..1
Association role: referenceableGrid	
Value type:	ReferenceableGridCoverage
Multiplicity:	0..1

5.2.5.1.9. SurfaceModel

SurfaceModel	
Subtype of:	AbstractSurfaceModel
Definition:	Surface coverage of geophysical properties
Description:	Horizontal or vertical cross section with polygons that represent rock bodies delineated by different geophysical properties. Examples: density section from 2D gravity modelling, geoelectric profile edited from a series of layer models. NOTE 1. Coverage data access may also be provided as explained in the metadata distribution options. .
Status:	Proposed
Stereotypes:	«featureType»
Attribute: modelType	
Value type:	SurfaceModelTypeValue
Multiplicity:	1
Association role: patches	
Value type:	MultiSurfaceCoverage
Multiplicity:	0..1

5.2.5.1.10. SurfaceScanning

SurfaceScanning	
Subtype of:	AbstractSurfaceMeasurement
Definition:	Geophysical measurement spatially referenced to a surface
Description:	Used to collect data along a surface, often by means of remote sensing
Status:	Proposed
Stereotypes:	«featureType»
Attribute: measurementType	
Value type:	SurfaceScanningTypeValue
Multiplicity:	1
Association role: samplingSurface	
Value type:	SF_SpatialSamplingFeature
Multiplicity:	0..1

5.2.5.1.11. XGeoph3DMeasurement

XGeoph3DMeasurement	
Subtype of:	AbstractGeoph3DMeasurement
Definition:	Geophysical measurement spatially referenced to a surface

XGeoph3DMeasurement	
Description:	Used to collect data on a surface. The extended model provides access to the sampling feature. Examples: 3D seismic measurement, 3D DC tomography. NOTE 1. Measured data access may be provided as explained in the metadata distribution options, or by the generic O&M mechanism through the related sampling feature. NOTE 2. Processing results of 3D measurements are usually solid coverages
Status:	Proposed
Stereotypes:	«featureType»
Attribute: measurementType	
Value type:	X3DMeasurementTypeValue
Multiplicity:	1
Association role: samplingFeature	
Value type:	SF_SamplingFeature
Multiplicity:	0..1

5.2.5.1.12. XGeophProfile

XGeophProfile	
Subtype of:	AbstractGeophProfile
Definition:	Extension to geophysical profile
Description:	The extended model provides access to the sampling feature. Geophysical profile is linked to Observation & Measurement classes through its samplingFeature association NOTE 1. If profileType is boreholeLogging, samplingFeature links to the samplingCurve of the GeologyCore::Borehole object in which borehole logging were carried out..
Status:	Proposed
Stereotypes:	«featureType»
Attribute: profileType	
Value type:	XProfileTypeValue
Multiplicity:	1
Association role: samplingCurve	
Value type:	SF_SamplingCurve
Multiplicity:	0..1

5.2.5.1.13. XGeophStation

XGeophStation	
Subtype of:	AbstractGeophStation
Definition:	Extension to geophysical station
Description:	The extended model provides access to the sampling feature. Geophysical station is linked to Observation & Measurement classes through its samplingPoint association
Status:	Proposed
Stereotypes:	«featureType»
Attribute: stationType	
Value type:	XStationTypeValue
Definition:	Type of geophysical measurement
Description:	provides access to the extended codelist

XGeophStation	
Multiplicity:	1
Association role: samplingPoint	
Value type:	SF_SamplingPoint
Multiplicity:	0..1

5.2.5.2. Data types

5.2.5.2.1. GeophProcedure

GeophProcedure	
Subtype of:	OM_Process
Definition:	Container for data about geophysical procedures
Description:	Can be any type of system description. Standard geophysical system descriptions (pe.: SPS, UKOOA, etc) are made available through distribution metadata. NOTE 1. Should be linked to the procedure association of OM_Observation
Status:	Proposed
Stereotypes:	«dataType»
Attribute: resource	
Value type:	Record
Definition:	resource of geophysical procedure
Description:	Provides access to any geophysical procedures in any format.
Multiplicity:	0..1
Attribute: standardResource	
Value type:	MD_Distribution
Definition:	geophysical procedure in wellknown Industrial standard format
Description:	Provides access to geophysical procedures or system descriptions in main geophysical standard formats (SPS, UKOOA, etc) Distribution information is suitable where data access requires contact with data provider.
Multiplicity:	0..1
Association role: conditions	
Value type:	Conditions
Multiplicity:	0..1
Association role: header	
Value type:	Header
Multiplicity:	0..1
Association role: instrumentation	
Value type:	Instrumentation
Multiplicity:	0..1

5.2.5.3. Enumerations

5.2.5.3.1. CampaignType

CampaignType	
Status:	Proposed
Stereotypes:	«enumeration»
Value: interpretation	

CampaignType
Value: measurement
Value: processing

5.2.5.4. Code lists

5.2.5.4.1. CurveModelTypeValue

CurveModelTypeValue	
Definition:	Externally handled codelist of curve model types.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: boreholeLog	
Definition:	Borehole log.
Description:	Distribution of geophysical properties along a borehole
Value: layerModel	
Definition:	Layer model
Description:	Geophysical properties in a sequence of infinite layers. Results are represented as line coverage along a straight line perpendicular to the layer boundaries, starting from the location of measurement, ending at the depth of penetration.

5.2.5.4.2. GeophPropertyTypeValue

GeophPropertyTypeValue	
Definition:	Externally handled codelist of geophysical property types.
Description:	To be developed. Provided items are examples.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: density	
Definition:	density (mass per volume)
Value: gravityBouguerAnomaly	
Definition:	Bouguer anomaly
Value: gravityFreeAirAnomaly	
Definition:	Bouguer anomaly
Value: resistivity	
Definition:	Electric resistivity
Value: salinity	
Definition:	Electric resistivity
Value: seismicReflectivity	
Definition:	Seismic reflectivity
Value: seismicVelocity	
Definition:	Electric resistivity
Value: totalMagneticField	
Definition:	Magnitude of the total magnetic field

5.2.5.4.3. SolidGridModelTypeValue

SolidGridModelTypeValue	
Definition:	Externally handled codelist
Description:	To be developed. Provided items are examples.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: parameterBlock	
Definition:	Model describing geophysical property distribution represented as a 3 dimensional grid.
Value: seismicVolume	
Definition:	Model describing seismic reflectivity distribution represented as a 3 dimensional grid.

5.2.5.4.4. SolidModelTypeValue

SolidModelTypeValue	
Definition:	Externally handled codelist
Description:	To be developed. Provided items are examples.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.

5.2.5.4.5. SurfaceGridModelTypeValue

SurfaceGridModelTypeValue	
Definition:	Surface grid model types
Description:	To be developed. Provided items are examples.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: horizontalParameterGrid	
Definition:	Model describing geophysical property distribution represented as a grid in a horizontal plain.
Value: seismicDepthSection	
Definition:	Model describing seismic reflectivity distribution represented as a grid in a vertical plain.
Value: verticalParameterGrid	
Definition:	Model describing geophysical property distribution represented as a grid in a vertical plain.

5.2.5.4.6. SurfaceModelTypeValue

SurfaceModelTypeValue	
Definition:	Surface model types
Description:	To be developed. Provided items are examples.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: horizontalCrossSection	
Definition:	Model describing geophysical property distribution represented as polygon patches in a horizontal plain.

SurfaceModelTypeValue
Value: verticallCrossSection
Definition: Model describing geophysical property distribution represented as polygon patches in a vertical plain.

5.2.5.4.7. SurfaceScanningTypeValue

SurfaceScanningTypeValue
Status: Proposed Stereotypes: «codeList» Governance: May be extended by Member States.
Value: radarBathimetry
Definition: Radar bathimetry measurement
Value: radarInterferometry
Definition: Radar interferometry measurement

5.2.5.4.8. X3DMeasurementTypeValue

X3DMeasurementTypeValue
Status: Proposed Stereotypes: «codeList» Governance: May be extended by Member States.
Value: 3DMultielectrodeDC
Definition: Complex electrode array to measure 3D electric reistivity data
Value: 3DSeismics

5.2.5.4.9. XDataSetTypeValue

XDataSetTypeValue
Definition: Externally handled codelist of geophysical property types. Description: To be developed. Provided items are examples. Status: Proposed Stereotypes: «codeList» Governance: May be extended by Member States.
Value: 1DResistivitySurvey
Definition: 1D resistivity survey. Vertical Electric Soundings
Value: 2DResistivitySurvey
Definition: 2D resistivity survey. Multielectrode DC profiles
Value: 2DSeismicSurvey
Definition: 2D seismic survey
Value: 3DResistivitySurvey
Definition: 3D resistivity survey. Multielectrode DC measurements
Value: 3DSeismicSurvey
Definition: 3D seismic survey
Value: airborneGeophysicalSurvey
Definition: Airborne geophysical survey
Value: boreholeLoggingSurvey

XDataSetTypeValue	
Definition:	Borehole logging survey
Value: frequencyDomainEMSurvey	
Definition:	Frequency domain EM survey
Value: gravityObservatoryDataSet	
Definition:	Data set from gravity field observatory
Value: gravitySurvey	
Definition:	Gravity survey
Value: magneticObservatoryDataSet	
Definition:	Data set from magnetic field observatory
Value: magneticSurvey	
Definition:	Magnetic measurement survey
Value: magnetotelluricSurvey	
Definition:	Magnetotelluric survey
Value: seismologicObservatoryDataSet	
Definition:	Data set from seismologic observatory
Value: seismologicSurvey	
Definition:	Data set from seismologic observatory
Value: timeDomainEMSurvey	
Definition:	Time domain EM survey

5.2.5.4.10. XProfileTypeValue

XProfileTypeValue	
Definition:	Externally handled codelist of geophysical property types.
Description:	To be developed. Provided items are examples.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: boreholeLogging	
Definition:	Geophysical measurement in a borehole
Value: conePenetrationTest	
Definition:	Cone penetration test
Value: flightLine	
Definition:	Geophysical measurements along a line carried out from an airplane or helicopter
Value: multielectrodeDCProfile	
Definition:	Multielectrode DC profile
Value: seismicLine	
Definition:	Seismic measurement alon a line
Value: verticalSeismicProfiling	
Definition:	Vertical seismic profile (VSP)

5.2.5.4.11. XStationTypeValue

XStationTypeValue	
Definition:	Externally handled codelist of geophysical property types.
Description:	To be developed. Provided items are examples.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: frequencyDomainEMSounding	
Definition:	Frequency domain electromagnetic sounding
Value: gravityStation	
Definition:	Gravity measurement station
Value: magneticStation	
Definition:	Magnetic measurement station
Value: magnetotelluricSounding	
Definition:	Magnetotelluric sounding
Value: seismologicalStation	
Definition:	Seismologic measurement station
Value: timeDomainEMSounding	
Definition:	Time domain electromagnetic sounding
Value: verticalElectricSounding	
Definition:	Vertical Electric Sounding

5.2.5.5. Imported types (informative)

This section lists definitions for feature types, data types and enumerations and code lists that are defined in other application schemas. The section is purely informative and should help the reader understand the feature catalogue presented in the previous sections. For the normative documentation of these types, see the given references.

5.2.5.5.1. AbstractGeoph3DMeasurement

AbstractGeoph3DMeasurement	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsCore [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	Abstract class for 3D Geophysical measurements
Description:	

5.2.5.5.2. AbstractGeophDataSet

AbstractGeophDataSet	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsCore [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	Generic feature type for geophysical datasets.
Description:	

5.2.5.5.3. AbstractGeophProfile

AbstractGeophProfile (abstract)

AbstractGeophProfile (abstract)	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsCore [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	Geophysical measurement spatially referenced to a curve
Description:	Used to collect data along a curve. Examples: 2D seismic measurement, borehole logging, airborne geophysical flight line NOTE1. Processing results of geophProfiles are often surface coverages

5.2.5.5.4. AbstractGeophStation

AbstractGeophStation (abstract)	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsCore [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	Geophysical measurement spatially referenced to a single point location
Description:	Used to collect data at a single location. The source-sensor setup may be alongated or two dimensional, but the collected data is referenced to a single point. Example: Gravity station, Magnetic station NOTE 1. Processing results of geophStations are often curve coverages

5.2.5.5.5. AbstractSurfaceMeasurement

AbstractSurfaceMeasurement	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsCore [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	Abstract class for Geophysical measurements spatially referenced to a surface

5.2.5.5.6. AbstractSurfaceModel

AbstractSurfaceModel (abstract)	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsCore [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	Abstract class for Surface models

5.2.5.5.7. CI_ResponsibleParty

CI_ResponsibleParty	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Citation and responsible party information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.8. GM_Curve

GM_Curve	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19107 Spatial Schema::ISO 19107:2003 Spatial Schema:: Geometry::Geometric primitive [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.9. GM_Solid

GM_Solid	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19107 Spatial Schema::ISO 19107:2003 Spatial Schema:: Geometry::Geometric primitive [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.10. GeophModel

GeophModel	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsCore [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	Generic feature type for geophysical models
Description:	Spatial distribution of physical properties. Usually it is the result of geophysical processing. It provides distribution of physical properties within the observed spatial domain.

5.2.5.5.11. MD_AggregateInformation

MD_AggregateInformation	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Identification information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.12. MD_Distribution

MD_Distribution	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Distribution information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.13. MappedFeature

MappedFeature	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::GeoSciML-Core::GeologicFeature [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.14. MultiSurfaceCoverage

MultiSurfaceCoverage	
Package:	INSPIRE Consolidated UML Model::Generic Conceptual Model::Base Models::Coverages (Geometry-Value Pairs) [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	coverage characterized by a finite domain consisting of surfaces
Description:	NOTE In most cases, the surfaces that constitute the domain of a coverage are mutually exclusive and exhaustively partition the extent of the coverage. Surfaces or their boundaries may be of any shape. The boundaries of component surfaces often correspond to natural phenomena and are highly irregular. EXAMPLE A coverage that represents soil types typically has a spatial domain composed of surfaces with irregular boundaries.

5.2.5.5.15. OM_Process

OM_Process (abstract)

OM_Process (abstract)	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19156 Observations and Measurements::ISO DIS 19156:2010 Observations and Measurements::Observation Core [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.16. Record

Record	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19103 Conceptual Schema Language::ISO 19103:2005 Schema Language::Basic Types::Implementation::Records and Class Metadata [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.17. RectifiedGridCoverage

RectifiedGridCoverage	
Package:	INSPIRE Consolidated UML Model::Generic Conceptual Model::Base Models::Coverages (Domain and Range) [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	coverage whose domain consists of a rectified grid
Description:	A rectified grid is a grid for which there is an affine transformation between the grid coordinates and the coordinates of a coordinate reference system. NOTE This type can be used for both discrete and continuous coverages.

5.2.5.5.18. ReferenceableGridCoverage

ReferenceableGridCoverage	
Package:	INSPIRE Consolidated UML Model::Generic Conceptual Model::Base Models::Coverages (Domain and Range) [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	coverage whose domain consists of a referencable grid
Description:	A referencable grid is a grid associated with a transformation that can be used to convert grid coordinate values to values of coordinates referenced to a coordinate reference system. NOTE This type can be used for both discrete and continuous coverages.

5.2.5.5.19. SF_SamplingCurve

SF_SamplingCurve	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19156 Observations and Measurements::ISO DIS 19156:2010 Observations and Measurements::Sampling Manifold::samplingCurve [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.20. SF_SamplingFeature

SF_SamplingFeature (abstract)	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19156 Observations and Measurements::ISO DIS 19156:2010 Observations and Measurements::Sampling Core [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.21. SF_SamplingPoint

SF_SamplingPoint

SF_SamplingPoint	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19156 Observations and Measurements::ISO DIS 19156:2010 Observations and Measurements::Sampling Manifold::samplingPoint [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.22. SF_SpatialSamplingFeature

SF_SpatialSamplingFeature (abstract)	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19156 Observations and Measurements::ISO DIS 19156:2010 Observations and Measurements::Sampling Manifold::spatialSamplingFeature [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.5.5.23. SeismicLineTypeValue

SeismicLineTypeValue	
Package:	INSPIRE Consolidated UML Model::Themes::Annex II::Geology::Geophysics::GeophysicsCore [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6 Feature catalogue

Table 3 - Feature catalogue metadata

Feature catalogue name	INSPIRE feature catalogue Hydrogeology
Scope	Hydrogeology
Version number	0.1
Version date	2010-10-27
Definition source	INSPIRE data specification Hydrogeology

Table 4 - Types defined in the feature catalogue

Type	Package	Stereotypes	Section
Aquiclude	Hydrogeology	«featureType»	5.2.2.1.1
Aquifer	Hydrogeology	«featureType»	5.2.2.1.2
AquiferDescription	Hydrogeology	«dataType»	5.2.2.2.1
AquiferSystem	Hydrogeology	«featureType»	5.2.2.1.3
Aquitard	Hydrogeology	«featureType»	5.2.2.1.4
GroundWaterBody	Hydrogeology	«featureType»	5.2.2.1.5
GroundWaterFlowSystem	Hydrogeology	«featureType»	5.2.2.1.6
GroundWaterIntake	Hydrogeology	«featureType»	5.2.2.1.7
GroundWaterMonitoringStation	Hydrogeology	«featureType»	5.2.2.1.8
GroundwaterSystem	Hydrogeology	«featureType»	5.2.2.1.9
HydrogeologicMappedFeature	Hydrogeology	«featureType»	5.2.2.1.10
HydrogeologicalObjectNatural	Hydrogeology	«featureType»	5.2.2.1.11
HydrogeologicalRelation	Hydrogeology	«featureType»	5.2.2.1.12
HydrogeologicalSystem	Hydrogeology	«featureType»	5.2.2.1.13
HydrogeologicalUnit	Hydrogeology	«featureType»	5.2.2.1.14
SpringOrSeep	Hydrogeology	«featureType»	5.2.2.1.15
StateOfGWB	Hydrogeology	«enumeration»	5.2.2.3.1

Type	Package	Stereotypes	Section
StationLevel	Hydrogeology	«enumeration»	5.2.2.3.2
StationType	Hydrogeology	«enumeration»	5.2.2.3.3
VanishingPoint	Hydrogeology	«featureType»	5.2.2.1.16
WaterPersistenceValue	Hydrogeology	«codeList»	5.2.2.4.1
WaterType	Hydrogeology	«enumeration»	5.2.2.3.4
WaterUseCode	Hydrogeology	«codeList»	5.2.2.4.2
WaterWell	Hydrogeology	«featureType»	5.2.2.1.17
WellPurposeCode	Hydrogeology	«codeList»	5.2.2.4.3
WellStatusCode	Hydrogeology	«codeList»	5.2.2.4.4
WellUse	Hydrogeology	«codeList»	5.2.2.4.5

5.2.6.1. Spatial object types

5.2.6.1.1. Aquiclude

Aquiclude

Subtype of: HydrogeologicalUnit

Definition: An impermeable body of rock or stratum of sediment that acts as a barrier to the flow of groundwater (From GWML) Impermeable beds of geologic material that hinder or prevent groundwater movement. http://www.groundwater.org/gi/gwglossary.html - Note -- (From GWML) A formation which, although porous and capable of absorbing water slowly, will not transmit water fast enough to furnish an appreciable supply for a well or spring. Aquicludes are characterized by very low values of "leakage" (the ratio of vertical *Hydraulic Conductivity* to thickness), so that they transmit only minor inter-aquifer flow and also have very low rates of yield from compressible storage. Therefore, they constitute boundaries of aquifer flow systems. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-a.pdf

Status: Proposed

Stereotypes: «featureType»

Attribute: hasLargeHorizontalExtend

Value type: boolean

Multiplicity: 1

Attribute: meanThickness

Value type: GEh_ValueType

Multiplicity: 1

Stereotypes: «voidable - estimatedProperty»

Attribute: orderNumberFromSurface

Value type: int

Multiplicity: 1

5.2.6.1.2. Aquifer

Aquifer

Subtype of: HydrogeologicalUnit

Definition: (From GWML) A formation, group of formations, or part of a formation that contains sufficient saturated, permeable material to yield significant quantities of water to wells and springs. (USGS) -- Note -- (From GWML) An underground geological formation able to store and yield water. http://www.groundwater.org/gi/gwglossary.html An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well. http://en.wikipedia.org/wiki/Aquifer"

Aquifer

Status: Proposed
Stereotypes: «featureType»

Attribute: IsMainInSystem

Value type: Boolean
Multiplicity: 1

Attribute: hasLargeHorizontalExtent

Value type: Boolean
Multiplicity: 1

Attribute: isConfined

Value type: Boolean
Multiplicity: 1

Attribute: isExploited

Value type: Boolean
Multiplicity: 1

Attribute: meanPermeabilityCoefficient

Value type: GEh_ValueType
Multiplicity: 1
Stereotypes: «voidable - estimatedProperty»

Attribute: meanThickness

Value type: GEh_ValueType
Multiplicity: 1
Stereotypes: «voidable - estimatedProperty»

Attribute: orderNumberFromSurface

Value type: int
Multiplicity: 1

Attribute: vulnerabilityToPollution

Value type: GEh_ValueType
Multiplicity: 1
Stereotypes: «voidable - estimatedProperty»

Association role: isCollectionOf

Value type: AquiferSystem
Multiplicity: 1

5.2.6.1.3. AquiferSystem

AquiferSystem

Subtype of: HydrogeologicalUnit
Definition: (From GWML) Collection of aquifers composing a system of interacting components. Aquifer System - A collection of all hydrogeological system elements, which together constitute the environment of groundwater - a " communicating vessels" filled or can be filled with water. Attributes of Aquifer System and its components determine the feasibility of water collection, its movement, as well as the impact on its chemical state. -- Note -- Aquifer System components and their attributes (including geometry) are the most stable over time except special cases.
Status: Proposed

AquiferSystem

Stereotypes: «featureType»

Attribute: isLayered

Value type: Boolean
Multiplicity: 1
Stereotypes: «voidable»

Association role: encloses

Value type: Aquiclude
Multiplicity: 1..*

Association role: formedBy

Value type: HydrogeologicalSystem
Multiplicity: 1

5.2.6.1.4. Aquitard

Aquitard

Subtype of: HydrogeologicalUnit
Definition: (From GWML) A saturated, but poorly permeable bed that impedes ground-water movement and does not yield water freely to wells, but which may transmit appreciable water to or from adjacent aquifers and, where sufficiently thick, may constitute an important ground-water storage unit. -- Note -- (From GWML) Aquitards are characterized by values of leakance that may range from relatively low to relatively high. Areally extensive aquitards of relatively low leakance may function regionally as boundaries of aquifer flow systems. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-a.pdf"
Status: Proposed
Stereotypes: «featureType»

Attribute: hesLargeHorizontalExtent

Value type: Boolean
Multiplicity: 1

Attribute: meanPermeabilityCoefficient

Value type: GEh_ValueType
Multiplicity: 1
Stereotypes: «voidable - estimatedProperty»

Attribute: meanThickness

Value type: GEh_ValueType
Multiplicity: 1
Stereotypes: «voidable - estimatedProperty»

Attribute: orderNumberFromSurface

Value type: int
Multiplicity: 1

Association role: isCollectionOf

Value type: AquiferSystem
Multiplicity: 1

5.2.6.1.5. GroundWaterBody

GroundWaterBody

GroundWaterBody	
Definition:	(From GWML) A distinct volume of groundwater within an aquifer or aquifers (Vogt, 2002). The equivalent in the European Water Framework Directive (2000/60/CE, 2000) is "Body of groundwater" defined exactly in the same way. -- Note -- GroundWaterBody may consist of smaller occurrences of GroundWaterBody and consequently can form a hierarchical structure (ComplexGroundWaterBody). Part of the occurrences in the hierarchy is WFDGroundWaterBody in AM theme. GroundWaterBody adjacent to the other GroundWaterBodys.
Status:	Proposed
Stereotypes:	«featureType»
Attribute: StateOfGroundWaterBody	
Value type:	StateOfGWB
Multiplicity:	1
Stereotypes:	«voidable»
Attribute: mineralization	
Value type:	WaterType
Multiplicity:	1
Stereotypes:	«voidable»
Association role:	
Value type:	GroundWaterBody
Multiplicity:	1
Association role:	
Value type:	GroundWaterBody
Multiplicity:	1..*
Association role:	
Value type:	GroundWaterBody
Multiplicity:	1..*
Association role:	
Value type:	GroundWaterBody
Multiplicity:	1
Association role: contains	
Value type:	GroundWaterFlowSystem
Multiplicity:	1
Association role: occurence	
Value type:	HydrogeologicMappedFeature
Multiplicity:	0..*

5.2.6.1.6. GroundWaterFlowSystem

GroundWaterFlowSystem	
Definition:	GroundWaterFlowSystem is created by groundwater bodies and both GroundWaterFlowSystem and GroundWaterFlowSystem change over time, and these changes are caused by external factors. -- Note -- Variable GroundWaterFlowSystem state defines the entire state of HydrogeologicalSystem. Frequently, such factors related to HydrogeologicalSystem and highly impact on the GroundWaterFlowSystem are the different human impacts, for example, groundwater intakes, drainage systems and hydro-weirs.

GroundWaterFlowSystem

Status: Proposed
Stereotypes: «featureType»

Attribute: stateOfFlowSystem

Value type: StateOfGWB
Multiplicity: 1

Association role: contains

Value type: HydrogeologicalSystem
Multiplicity: 1

5.2.6.1.7. GroundWaterIntake

GroundWaterIntake

Definition: Group of wells closely situated and interacting with each other. Most linked by a common collector gathering water pumped in the individual well.
Status: Proposed
Stereotypes: «featureType»

Attribute: hasProtectionZone

Value type: boolean
Multiplicity: 1
Stereotypes: «voidable»

Attribute: waterUsage

Value type: WaterUseCode
Multiplicity: 1
Stereotypes: «voidable»

5.2.6.1.8. GroundWaterMonitoringStation

GroundWaterMonitoringStation

Subtype of: MonitoringFacility
Definition: Class GroundWaterMonitoringStation realizes class Station from ISO 19156 standard in hydrogeology domain.
Status: Proposed
Stereotypes: «featureType»

Attribute: level

Value type: StatonLevel
Multiplicity: 1
Stereotypes: «voidable»

Attribute: type

Value type: StationType
Multiplicity: 1
Stereotypes: «voidable»

5.2.6.1.9. GroundwaterSystem

GroundwaterSystem

Status: Proposed
Stereotypes: «featureType»

Association role: member

Value type: GroundWaterFlowSystem
Multiplicity: 0..*

GroundwaterSystem

Association role: member

Value type: GroundWaterBody
Multiplicity: 0..*

Association role: member

Value type: HydrogeologicalSystem
Multiplicity: 0..*

5.2.6.1.10. HydrogeologicMappedFeature

HydrogeologicMappedFeature

Subtype of: MappedFeature
Definition: HydrogeologicalMappedFeature is a geometric representation of a GroundwaterBody. -- Note -- Class equivalent to MappedFeature in GeoSciML with the restriction, that it is used for groundwater bodies. As HydrogeologicalUnit is a subclass of GeologicFeature that class and its subclasses can use the MappedFeature modeling pattern to represent their geometries.
Status: Proposed
Stereotypes: «featureType»

Attribute: dateOfValidity

Value type: TM_Object
Definition: MappedFeature in hydrogeology are quite variable over time. This property defines over what time period this geometry actually make sense.
Multiplicity: 1

5.2.6.1.11. HydrogeologicalObjectNatural

HydrogeologicalObjectNatural

Status: Proposed
Stereotypes: «featureType»

Attribute: waterPersistance

Value type: WaterPersistanceValue
Multiplicity: 1
Stereotypes: «voidable - estimatedProperty»

5.2.6.1.12. HydrogeologicalRelation

HydrogeologicalRelation

Subtype of: GeologicRelation
Status: Proposed
Stereotypes: «featureType»

Association role: source

Value type: HydrogeologicalUnit
Multiplicity: 1

5.2.6.1.13. HydrogeologicalSystem

HydrogeologicalSystem

HydrogeologicalSystem	
Definition:	Part of the Earth's crust which is the environment consisting of a groundwater aquifer system (Aquifer System - invariable in time) and filled with the groundwater flow system (Groundwater Flow System - variable in time). Both these components are complex, interrelated and their components are also interrelated. -- Note -- General hydrogeological relationships in the system: - External Factors (External Factors, EF) influence the HydrogeologicalSystem. - The HydrogeologicalSystem response to these factors (EF) determined by the properties of the system (Aquifer System). - The answer to the HydrogeologicalSystem state of EF shall be expressed by GWFS. A detailed description of these relationships and elements that shape them contain a classes derived from classes GroundWaterFlowSystem and AquiferSystem or are related to them.
Status:	Proposed
Stereotypes:	«featureType»
Attribute: isMain	
Value type:	Boolean
Multiplicity:	1
Stereotypes:	«voidable»
Association role: member	
Value type:	HydrogeologicalUnit
Multiplicity:	0..*

5.2.6.1.14. HydrogeologicalUnit

HydrogeologicalUnit (abstract)	
Subtype of:	GeologicUnit
Definition:	Means any soil of rock unit or zone which by virtue of its porosity or permeability, or lack thereof, has a distinct influence on the storage or movement of groundwater. (EPA) Hydrogeological unit is almost always invariable in time. -- Note -- Examples of hydrogeological units: aquifer, aquitard, aquiclude, aquifer system, hydrogeological system Groundwater flow system and groundwater body are not hydrogeological units.
Status:	Proposed
Stereotypes:	«featureType»
Attribute: isComplex	
Value type:	boolean
Multiplicity:	1
Stereotypes:	«voidable»
Association role: targetLink	
Value type:	HydrogeologicalRelation
Multiplicity:	0..*

5.2.6.1.15. SpringOrSeep

SpringOrSeep	
Subtype of:	HydrogeologicalObjectNatural, HydroPointOfInterest
Definition:	A natural outflow of water from below the ground surface.
Description:	NOTE 1 Corresponds to a 'source' node in a network view. NOTE 2 Regarded as a placeholder in Annex II theme 'Geology' due to the connection with groundwater.
Status:	Proposed
Stereotypes:	«featureType»

5.2.6.1.16. VanishingPoint

VanishingPoint	
Subtype of:	HydrogeologicalObjectNatural, HydroPointOfInterest
Definition:	Location where a watercourse disappears into the terrain or vanishes due to anthropization.
Description:	NOTE 1 Corresponds to an 'outlet' node in a network view. NOTE 2 Regarded as a placeholder in Annex II theme 'Geology' due to the connection with groundwater.
Status:	Proposed
Stereotypes:	«featureType»

5.2.6.1.17. WaterWell

WaterWell	
Subtype of:	SF_SamplingFeature, SF_SamplingPoint, SF_SamplingCurve
Definition:	An excavation where the intended use is for location, acquisition, development, or artificial recharge of ground water. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-w.pdf A water well is an excavation or structure created in the ground ? by digging, driving, boring or drilling to access water in underground aquifers. http://en.wikipedia.org/wiki/Water_well
Status:	Proposed
Stereotypes:	«featureType»
Attribute: onlineResource	
Value type:	CI_OnlineResource
Definition:	Reference to an external online representation (URI, web page, URN)
Multiplicity:	0..1
Attribute: referenceElevation	
Value type:	Measure
Definition:	Elevation from which other elevation are calculated (such as Water Level)
Multiplicity:	1
Attribute: waterUse	
Value type:	WaterUseCode
Definition:	The use of water may be classified by specific types according to distinctive uses. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-w.pdf Can be agriculture, commercial, domestic, heat transfer, industrial, irrigation, municipal, other, unknown, public recreation, research. Groundwater Data Management Guidelines, Environment Canada, Dec. 1991
Multiplicity:	0..*
Attribute: wellDepth	
Value type:	CGI_NumericRange
Definition:	Depth of the well
Multiplicity:	1
Attribute: wellPurpose	
Value type:	WellPurposeCode
Definition:	Purpose of the well. Can be cathodic protection, coalELog, core, decontamination, Dewatering, Disposal, FlowingShot, Geotechnical, Mineral, MonitoringlevelHead, MonitoringQuality, Oil, OilExploratory, Recharge, Seismic, WaterExploratory, WaterSupply, Other. Groundwater Data Management Guidelines, Environment Canada, Dec. 1991
Multiplicity:	0..*

WaterWell	
Attribute: wellStatus	
Value type:	WellStatusCode
Definition:	Status of the well, Can be new, unfinished, reconditioned, deepened, not in use, standby, unknown, abandoned dry, abandoned insufficient, abandoned quality. Groundwater Data Management Guidelines, Environment Canada, Dec. 1991
Multiplicity:	1
Attribute: wellType	
Value type:	CGI_Term
Definition:	Type of wells, related to the way they are build, eg: Dug Well, Drilled Well..
Multiplicity:	1
Attribute: wellUse	
Value type:	WellUse
Definition:	Well use represents what the well is used for (monitoring, production) while water use is what the water is destined for (agriculture, domestic, industry), For example a Monitoring well on a farm.
Multiplicity:	0..*
Association role:	
Value type:	GroundWaterMonitoringStation
Multiplicity:	0..1
Association role:	
Value type:	GroundWaterIntake
Multiplicity:	0..1
Association role: indexData	
Value type:	BoreholeDetails
Multiplicity:	0..1

5.2.6.2. Data types

5.2.6.2.1. AquiferDescription

AquiferDescription	
Definition:	(From GWML) Properties of the rock (forming aquifer) that is relevant to the groundwater.
Status:	Proposed
Stereotypes:	«dataType»
Attribute: beginLifespanVersion	
Value type:	DateTime
Multiplicity:	1
Stereotypes:	«lifeCycleInfo - voidable»
Attribute: capacityCoefficient	
Value type:	GEh_ValueType
Multiplicity:	1
Stereotypes:	«voidable - estimatedProperty»
Attribute: descriptoin	
Value type:	LocalizedString
Multiplicity:	1
Stereotypes:	«voidable»

AquiferDescription
Attribute: endLifespanVersion Value type: DateTime Multiplicity: 0..1 Stereotypes: «lifeCycleInfo - voidable»
Attribute: hydraulicConductivityCoefficient Value type: GEh_ValueType Multiplicity: 1 Stereotypes: «voidable - estimatedProperty»
Attribute: storativityCoefficient Value type: GEh_ValueType Multiplicity: 1 Stereotypes: «voidable - estimatedProperty»
Association role: Value type: Aquitard Multiplicity: 1
Association role: Value type: Aquifer Multiplicity: 1

5.2.6.3. Enumerations

5.2.6.3.1. StateOfGWB

StateOfGWB
Definition: GroundWaterFlowSystem and its parts (GroundWaterBody) are variable during the state dependent on external factors, which are the most diverse human activities. Enumeration StateOf determines the approximate degree of these changes. Status: Proposed Stereotypes: «enumeration»
Value: lightlyModified
Value: modified
Value: natural
Value: stronglyModified

5.2.6.3.2. StationLevel

StationLevel
Status: Proposed Stereotypes: «enumeration»
Value: baseLine
Value: basicNetwork
Value: hydrologicalBenchmark
Value: specificNetwork

StationLevel
Value: temporalNetwork

5.2.6.3.3. StationType

StationType	
Status:	Proposed
Stereotypes:	«enumeration»
Value: quality	
Value: quantity	

5.2.6.3.4. WaterType

WaterType	
Definition:	(From GWML) This enumeration class refers to the concept of salinity and its classes in water. -- Note -- (From GWML) Salinity is the saltiness or dissolved salt content of a body of water. http://en.wikipedia.org/wiki/Salinity Generally, the concentration of mineral salts dissolved in water. Salinity may be expressed in terms of a concentration or as electrical conductivity. When describing salinity influenced by seawater, salinity often refers to the concentration of chlorides in the water. See also total dissolved solids. http://www.groundwater.water.ca.gov/groundwater_basics/gwb_glossary/index.cfm#ss
Status:	Proposed
Stereotypes:	«enumeration»
Value: acratopegae	
Value: brackishWater	
Value: brineWater	
Value: freshWater	
Value: saltWater	
Value: ultraFreshWater	

5.2.6.4. Code lists

5.2.6.4.1. WaterPersistenceValue

WaterPersistenceValue	
Definition:	Categories of hydrological persistence of water. (from GWML - modified)
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May not be extended by Member States. Centrally managed in INSPIRE code list register. URN: urn:x-inspire:def:codeList:INSPIRE:HydrologicalPersistenceValue
Value: ephemeral	
Definition:	Filled and/or flowing during and immediately after precipitation.
Description:	SOURCE [DFDD].
Value: intermittent	
Definition:	Filled and/or flowing for part of the year.
Description:	SOURCE [DFDD].

WaterPersistenceValue
Value: perennial Definition: Filled and/or flowing continuously throughout the year as its bed lies below the water table. Description: SOURCE [DFDD].
Value: seasonal

5.2.6.4.2. WaterUseCode

WaterUseCode
Definition: The use of water may be classified by specific types according to distinctive uses. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-w.pdf Status: Proposed Stereotypes: «codeList» Governance: May be extended by Member States.
Value: Agriculture
Value: Commercial
Value: Domestic
Value: HeatTransfert
Value: Industrial
Value: Irrigation
Value: Municipal
Value: OtherUnknow
Value: PublicRecreation
Value: Research

5.2.6.4.3. WellPurposeCode

WellPurposeCode
Definition: Code associated to define the purpose of the well. Status: Proposed Stereotypes: «codeList» Governance: May be extended by Member States.
Value: cathodicProtection
Value: coalELog
Value: core
Value: decontamination
Value: dewatering
Value: disposal

WellPurposeCode
Value: flowingShot
Value: geotechnical
Value: mineral
Value: monitoringLevelHead
Value: monitoringQuality
Value: oil
Value: oilExploratory
Value: other
Value: recharge
Value: seismic
Value: termal
Value: waterExploratory
Value: waterSupply
Value: withdrawal

5.2.6.4.4. WellStatusCode

WellStatusCode	
Definition:	(from GWML) Status of the well. -- Note -- Class adapted from GWML.
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: abandoned	
Value: abandonedDry	
Value: abandonedInsufficient	
Value: abandonedQuality	
Value: deepened	
Value: new	
Value: notInUse	
Value: reconditionned	
Value: standby	
Value: unfinished	

WellStatusCode
Value: unknown

5.2.6.4.5. WellUse

WellUse	
Definition:	A list of terms for well use
Status:	Proposed
Stereotypes:	«codeList»
Governance:	May be extended by Member States.
Value: domestic	
Value: exploitation	
Value: monitoring	
Value: observation	
Value: piezometry	
Value: production	

5.2.6.5. Imported types (informative)

This section lists definitions for feature types, data types and enumerations and code lists that are defined in other application schemas. The section is purely informative and should help the reader understand the feature catalogue presented in the previous sections. For the normative documentation of these types, see the given references.

5.2.6.5.1. Boolean

Boolean	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19103 Conceptual Schema Language::ISO 19103:2005 Schema Language::Basic Types::Primitive::Truth [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.2. BoreholeDetails

BoreholeDetails	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::Borehole [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.3. CGI_NumericRange

CGI_NumericRange	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::CGI_Utilities::CGI_Value [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.4. CGI_Term

CGI_Term	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::CGI_Utilities::CGI_Value [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.5. CI_OnlineResource

CI_OnlineResource	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19115-All Metadata::ISO 19115:2006 Metadata (Corrigendum)::Citation and responsible party information [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.6. DateTime

DateTime	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19103 Conceptual Schema Language::ISO 19103:2005 Schema Language::Basic Types::Primitive::Date and Time [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.7. GeologicRelation

GeologicRelation (abstract)	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::GeoSciML-Core::GeologicRelation [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.8. GeologicUnit

GeologicUnit	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::GeoSciML-Core::GeologicUnit [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.9. HydroPointOfInterest

HydroPointOfInterest (abstract)	
Package:	INSPIRE Consolidated UML Model::Themes::Annex I::Hydrography::Hydro - Physical Waters [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	A natural place where water appears, disappears or changes its flow.
Description:	EXAMPLE Fluvial points (waterfall, cascade, rapids, breaker), spring/water hole (spring, source, geyser, thermal spring, natural fountain, well, also fumarole, artesian), sinkhole (sinkhole, drainage loss). NOTE A hydro point of interest may create a flow constriction in the network.

5.2.6.5.10. MappedFeature

MappedFeature	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::GeoSciML::GeoSciML-Core::GeologicFeature [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.11. Measure

Measure	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19103 Conceptual Schema Language::ISO 19103:2005 Schema Language::Basic Types::Derived::Units of Measure [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.12. MonitoringFacility

MonitoringFacility	
Package:	INSPIRE Consolidated UML Model::Themes::Annex III::Environmental Monitoring Facilities::EF_Model_V1 [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]
Definition:	A facility at/from which instruments are hosted or deployed to undertake environmental monitoring (insitu or remotely sensed); either a static observation site or a moving platform.

5.2.6.5.13. SF_SamplingCurve

SF_SamplingCurve	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19156 Observations and Measurements::ISO DIS 19156:2010 Observations and Measurements::Sampling Manifold::samplingCurve [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.14. SF_SamplingFeature

SF_SamplingFeature (abstract)	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19156 Observations and Measurements::ISO DIS 19156:2010 Observations and Measurements::Sampling Core [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.15. SF_SamplingPoint

SF_SamplingPoint	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19156 Observations and Measurements::ISO DIS 19156:2010 Observations and Measurements::Sampling Manifold::samplingPoint [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

5.2.6.5.16. TM_Object

TM_Object	
Package:	INSPIRE Consolidated UML Model::Foundation Schemas::ISO TC211::ISO 19108 Temporal schema::ISO 19108:2006 Temporal Schema::Temporal Objects [Include reference to the document that includes the package, e.g. INSPIRE data specification, ISO standard or the GCM]

6 Reference systems

6.1 Coordinate reference systems

6.1.1 Datum

IR Requirement 3	For the coordinate reference systems used for making available the INSPIRE spatial data sets, the datum shall be the datum of the European Terrestrial

Reference System 1989 (ETRS89) in areas within its geographical scope, and the datum of the International Terrestrial Reference System (ITRS) or other geodetic coordinate reference systems compliant with ITRS in areas that are outside the geographical scope of ETRS89. Compliant with the ITRS means that the system definition is based on the definition of the ITRS and there is a well established and described relationship between both systems, according to EN ISO 19111.

6.1.2 Coordinate reference systems

IR Requirement 4 INSPIRE spatial data sets shall be made available using one of the three-dimensional, two-dimensional or compound coordinate reference systems specified in the list below.

Other coordinate reference systems than those listed below may only be used for regions outside of continental Europe. The geodetic codes and parameters for these coordinate reference systems shall be documented, and an identifier shall be created, according to EN ISO 19111 and ISO 19127.

1. Three-dimensional Coordinate Reference Systems
   - Three-dimensional Cartesian coordinates
   - Three-dimensional geodetic coordinates (latitude, longitude and ellipsoidal height), using the parameters of the GRS80 ellipsoid

2. Two-dimensional Coordinate Reference Systems
   - Two-dimensional geodetic coordinates, using the parameters of the GRS80 ellipsoid
   - Plane coordinates using the Lambert Azimuthal Equal Area projection and the parameters of the GRS80 ellipsoid
   - Plane coordinates using the Lambert Conformal Conic projection and the parameters of the GRS80 ellipsoid
   - Plane coordinates using the Transverse Mercator projection and the parameters of the GRS80 ellipsoid

3. Compound Coordinate Reference Systems
   - For the horizontal component of the compound coordinate reference system, one of the two-dimensional coordinate reference systems specified above shall be used
   - For the vertical component on land, the European Vertical Reference System (EVRS) shall be used to express gravity-related heights within its geographical scope
   - Other vertical reference systems related to the Earth gravity field shall be used to express gravity-related heights in areas that are outside the geographical scope of EVRS. The geodetic codes and parameters for these vertical reference systems shall be documented and an identifier shall be created, according to EN ISO 19111 and ISO 19127
   - For the vertical component measuring the depth of the sea floor, where there is an appreciable tidal range, the Lowest Astronomical Tide shall be used as reference surface. In marine areas without an appreciable tidal range, in open oceans and effectively in waters that are deeper than 200 m, the depth of the sea floor shall be referenced to the Mean Sea Level
   - For the vertical component measuring depths above the sea floor in the free ocean, barometric pressure shall be used
   - For the vertical component in the free atmosphere, barometric pressure, converted to height using ISO 2533:1975 International Standard Atmosphere shall be used

6.1.3 Display

IR Requirement 5 For the display of the INSPIRE spatial data sets with the View Service specified in D003152/02 Draft Commission Regulation implementing Directive 2007/2/EC

of the European Parliament and of the Council as regards Network Services, at least the two dimensional geodetic coordinate system shall be made available.

6.1.4 Identifiers for coordinate reference systems

IR Requirement 6 For referring to the non-compound coordinate reference systems listed in this Section, the identifiers listed below shall be used.

For referring to a compound coordinate reference system, an identifier composed of the identifier of the horizontal component, followed by a slash (/), followed by the identifier of the vertical component, shall be used.

- ETRS89-XYZ for Cartesian coordinates in ETRS89
- ETRS89-GRS80h for three-dimensional geodetic coordinates in ETRS89 on the GRS80 ellipsoid
- ETRS89-GRS80 for two-dimensional geodetic coordinates in ETRS89 on the GRS80
- EVRS for height in EVRS
- LAT for depth of the sea floor, where there is an appreciable tidal range
- MSL for depth of the sea floor, in marine areas without an appreciable tidal range, in open oceans and effectively in waters that are deeper than 200m
- ISA for pressure coordinate in the free atmosphere
- PFO for Pressure coordinate in the free ocean
- ETRS89-LAEA for ETRS89 coordinates projected into plane coordinates by the Lambert Azimuthal Equal Area projection
- ETRS89-LCC for ETRS89 coordinates projected into plane coordinates by the Lambert Conformal Conic projection
- ETRS89-TMzn for ETRS89 coordinates projected into plane coordinates by the Transverse Mercator projection

6.2 Temporal reference system

IR Requirement 7 The Gregorian Calendar shall be used for as a reference system for date values, and the Universal Time Coordinated (UTC) or the local time including the time zone as an offset from UTC shall be used as a reference system for time values.

6.3 Theme-specific requirements and recommendations on reference systems

There are no theme-specific requirements or recommendations on reference systems.

7 Data quality

This chapter includes a description of data quality elements and sub-elements as well as the associated basic data quality measures to be used to describe data related to the spatial data theme *Geology* (see Table 1). The data quality elements are described in section 7.1.

NOTE Additional guidance documents on procedures and methods that can be used to implement the basic data quality measures introduced in this section will be provided at a later stage.

In addition, recommendations on minimum data quality are included for specific elements. These recommendations are included in section 7.2.

7.1 Data quality elements

Data quality information can be described at level of spatial object (feature), spatial object type (feature type), dataset or dataset series. Data quality information at spatial object level is modelled directly in the application schema (Chapter 5).

Recommendation 2 Aggregated data quality information should ideally be collected at the level of spatial object types and included in the dataset (series) metadata.

Chapter 8 describes the corresponding metadata elements to report about this data quality information.

List all data quality elements used in the application schema in the following table. Delete the data quality elements which are not appropriate for the theme.

Table 3 – List of all data quality elements used in the spatial data theme Geology

Section	**Data quality element and sub-elements** **Data quality sub-element**	**Scope(s)**
7.1.1	Positional accuracy – Absolute or external accuracy	spatial object type

Delete any of the following subsections, if they are not applicable for this data specification.

7.1.1 Positional accuracy – Absolute or external accuracy

Name	One-dimensional random variable
Alternative name	accuracy
Data quality element	Positional accuracy
Data quality sub-element	Absolute or external accuracy
Data quality basic measure	One-dimensional random variable
Definition	An indication of the accuracy of the data set as an aggregate
Description	This measure is an indication of the accuracy of the features within the data set
Parameter	
Data quality value type	Real
Data quality value structure	
Source reference	
Example	
Measure identifier	

7.2 Minimum data quality recommendations

No recommendations on minimum data quality are defined in this data specification.

8 Dataset-level metadata

Metadata can be reported for each individual spatial object (spatial object-level metadata) or once for a complete dataset or dataset series (dataset-level metadata). Spatial object-level metadata is fully described in the application schema (section **5**). If data quality elements are used at spatial object level, the documentation shall refer to the appropriate definition in section 7. This section only specifies dataset-level metadata elements.

For some dataset-level metadata elements, in particular on data quality and maintenance, a more specific scope can be specified. This allows the definition of metadata at sub-dataset level, e.g. separately for each spatial object type. When using ISO 19115/19139 to encode the metadata, the following rules should be followed:

- The scope element (of type DQ_Scope) of the DQ_DataQuality subtype should be used to encode the scope.
- Only the following values should be used for the level element of DQ_Scope: Series, Dataset, featureType.
- If the level is featureType the levelDescription/MDScopeDescription/features element (of type Set< GF_FeatureType>) shall be used to list the feature type names.

NOTE The value featureType is used to denote spatial object type.

Mandatory or conditional metadata elements are specified in Section 8.1. Optional metadata elements are specified in Section 8.2. The tables describing the metadata elements contain the following information:

- The first column provides a reference to a more detailed description.
- The second column specifies the name of the metadata element.
- The third column specifies the multiplicity.
- The fourth column specifies the condition, under which the given element becomes mandatory (only for Table 4 and Table 5).

8.1 Common metadata elements

IR Requirement 8	The metadata describing a spatial data set or a spatial data set series related to the theme **Geology** shall comprise the metadata elements required by Regulation 1205/2008/EC (implementing Directive 2007/2/EC of the European Parliament and of the Council as regards metadata) for spatial datasets and spatial dataset series (Table 4) as well as the metadata elements specified in Table 5.

Table 4 – Metadata for spatial datasets and spatial dataset series specified in Regulation 1205/2008/EC (implementing Directive 2007/2/EC of the European Parliament and of the Council as regards metadata)

Metadata Regulation Section	Metadata element	Multiplicity	Condition
1.1	Resource title	1	
1.2	Resource abstract	1	
1.3	Resource type	1	

1.4	Resource locator	0..*	Mandatory if a URL is available to obtain more information on the resource, and/or access related services.
1.5	Unique resource identifier	1..*	
1.7	Resource language	0..*	Mandatory if the resource includes textual information.
2.1	Topic category	1..*	
3	Keyword	1..*	
4.1	Geographic bounding box	1..*	
5	Temporal reference	1..*	
6.1	Lineage	1	
6.2	Spatial resolution	0..*	Mandatory for data sets and data set series if an equivalent scale or a resolution distance can be specified.
7	Conformity	1..*	
8.1	Conditions for access and use	1..*	
8.2	Limitations on public access	1..*	
9	Responsible organisation	1..*	
10.1	Metadata point of contact	1..*	
10.2	Metadata date	1	
10.3	Metadata language	1	

Table 5 – Mandatory and conditional common metadata elements

INSPIRE Data Specification Geology **Section**	**Metadata element**	**Multiplicity**	**Condition**
8.1.1	Coordinate Reference System	1	
8.1.2	Temporal Reference System	0..*	Mandatory, if the spatial data set or one of its feature types contains temporal information that does not refer to the Gregorian Calendar or the Coordinated Universal Time.
8.1.3	Encoding	1..*	
8.1.4	Character Encoding	0..*	Mandatory, if an encoding is used that is not based on UTF-8.

8.1.1 Coordinate Reference System

Metadata element name	**Coordinate Reference System**
Definition	Description of the coordinate reference system used in the dataset.
ISO 19115 number and name	13. referenceSystemInfo
ISO/TS 19139 path	referenceSystemInfo
INSPIRE obligation / condition	mandatory
INSPIRE multiplicity	1
Data type(and ISO 19115 no.)	189. MD_CRS
Domain	Either the referenceSystemIdentifier (RS_Identifier) or the projection (RS_Identifier), ellipsoid (RS_Identifier) and datum (RS_Identifier) properties shall be provided. *More specific instructions, in particular on pre-defined values for filling the referenceSystemIdentifier attribute shall be provided by the TWG RS.*
Implementing instructions	<instructions on how the metadata can be obtained>
Example	referenceSystemIdentifier: code: ETRS_89 codeSpace: INSPIRE RS registry
Example XML encoding	
Comments	

8.1.2 Temporal Reference System

Metadata element name	**Temporal Reference System**
Definition	Description of the temporal reference systems used in the dataset.
ISO 19115 number and name	13. referenceSystemInfo
ISO/TS 19139 path	referenceSystemInfo
INSPIRE obligation / condition	Mandatory, if the spatial data set or one of its feature types contains temporal information that does not refer to the Gregorian Calendar or the Coordinated Universal Time.
INSPIRE multiplicity	0..*
Data type(and ISO 19115 no.)	186. MD_ReferenceSystem
Domain	No specific type is defined in ISO 19115 for temporal reference systems. Thus, the generic MD_ReferenceSystem element and its reference SystemIdentifier (RS_Identifier) property shall be provided. *More specific instructions, in particular on pre-defined values for filling the referenceSystemIdentifier attribute shall be provided by DT/CT.*
Implementing instructions	<instructions on how the metadata can be obtained>
Example	referenceSystemIdentifier: code: GregorianCalendar codeSpace: INSPIRE RS registry
Example XML encoding	
Comments	

8.1.3 Encoding

Metadata element name	**Encoding**
Definition	Description of the computer language construct that specifies the representation of data objects in a record, file, message, storage device or transmission channel
ISO 19115 number and name	271. distributionFormat

ISO/TS 19139 path	distributionInfo/MD_Distribution/distributionFormat
INSPIRE obligation / condition	mandatory
INSPIRE multiplicity	1
Data type (and ISO 19115 no.)	284. MD_Format
Domain	See B.2.10.4. The following property values shall be used for default and alternative encodings specified in section **Erreur ! Source du renvoi introuvable.**: Default Encoding – name: **Geology** GML application schema – version: version <version of this specification>; GML, version 3.2.1 – specification: D2.8.**II/III.4** Data Specification on **Geology** – Draft Guidelines Alternative Encoding *Include one paragraph for each alternative encoding defined in section **Erreur ! Source du renvoi introuvable.**.* – name: <Encoding name> – version: version <version of the encoding> – specification: <specification>
Implementing instructions	<instructions on how the metadata can be obtained>
Example	name: **Geology** GML application schema version: version 3.0, GML, version 3.2.1 specification: D2.8.**II/III.4** Data Specification on **Geology** – Draft Guidelines
Example XML encoding	
Comments	<comments>

8.1.4 Character Encoding

Metadata element name	**Character Encoding**
Definition	The character encoding used in the data set.
ISO 19115 number and name	
ISO/TS 19139 path	
INSPIRE obligation / condition	Mandatory, if an encoding is used that is not based on UTF-8.
INSPIRE multiplicity	0..*
Data type (and ISO 19115 no.)	
Domain	
Implementing instructions	
Example	-
Example XML encoding	-
Comments	

8.2 Theme-specific metadata elements

IR Requirement 9	The metadata describing a spatial data set or a spatial data set series related to the theme *Geology* shall also comprise the theme-specific **metadata elements specified in Erreur ! Source du renvoi introuvable.**.

Recommendation 3 The metadata describing a spatial data set or a spatial data set series related to the theme *Geology* should comprise the theme-specific metadata elements specified in Table 6.

Table 6 – Optional theme-specific metadata elements for the theme *Geology*

INSPIRE Data Specification *Geology* Section	**Metadata element**	**Multiplicity**
8.2.1	Maintenance information	0..1

8.2.1 Maintenance information

Metadata element name	Maintenance information
Definition	information about the scope and frequency of updating
ISO 19115 number and name	30. resourceMaintenance
ISO/TS 19139 path	identificationInfo/MD_Identification/resourceMaintenance
INSPIRE obligation / condition	optional
INSPIRE multiplicity	0..1
Data type (and ISO 19115 no.)	142. MD_MaintenanceInformation
Domain	This is a complex type (lines 143-148 from ISO 19115). At least the following elements should be used (the multiplicity according to ISO 19115 is shown in parentheses): − maintenanceAndUpdateFrequency [1]: frequency with which changes and additions are made to the resource after the initial resource is completed / domain value: MD_MaintenanceFrequencyCode: − maintenanceNote [0..*]: information regarding specific requirements for maintaining the resource / domain value: free text
Implementing instructions (optional)	
Example (optional)	
Example XML encoding (optional)	
Comments (optional)	

8.3 Guidelines on using metadata elements defined in Regulation 1205/2008/EC

8.3.1 Conformity

The *Conformity* metadata element defined in Regulation 1205/2008/EC allows to report the conformance with the Implementing Rule for interoperability of spatial data sets and services or another specification. The degree of conformity of the dataset can be *Conformant* (if the dataset is fully conformant with the cited specification), *Not Conformant* (if the dataset does not conform to the cited specification) or *Not evaluated* (if the conformance has not been evaluated).

Recommendation 4 The Conformity metadata element should be used to report conceptual consistency with this INSPIRE data specification. The value of Conformant should be used for the Degree element only if the dataset passes all the requirements described in the abstract test suite presented in Annex A. The Specification element should be given as follows:
- title: “INSPIRE Data Specification on <Theme Name> – Draft Guidelines”
- date:
  - dateType: publication
  - date: 2011-04-30

8.3.2 Lineage

Following the ISO 19113 Quality principles, if a data provider has a procedure for quality validation of their spatial data sets then the data quality elements listed in the Chapter 8 should be used. If not, the *Lineage* metadata element (defined in Regulation 1205/2008/EC) should be used to describe the overall quality of a spatial data set.

According to Regulation 1205/2008/EC, lineage “is a statement on process history and/or overall quality of the spatial data set. Where appropriate it may include a statement whether the data set has been validated or quality assured, whether it is the official version (if multiple versions exist), and whether it has legal validity. The value domain of this metadata element is free text”.

Recommendation 5 Apart from describing the process history, if feasible within a free text, the overall quality of the dataset (series) should be included in the *Lineage* metadata element. This statement should contain any quality information required for interoperability and/or valuable for use and evaluation of the data set (series).

8.3.3 Temporal reference

According to Regulation 1205/2008/EC, at least one of the following temporal reference metadata elements shall be provided: temporal extent, date of publication, date of last revision, date of creation.

Recommendation 6 If feasible, the date of the last revision of a spatial data set should be reported using the *Date of last revision* metadata element.

9 Delivery

9.1 Delivery medium

DS Requirement 2	Data conformant to this INSPIRE data specification shall be made available through an INSPIRE network service.

DS Requirement 3	All information that is required by a calling application to be able to retrieve the data through the used network service shall be made available in accordance with the requirements defined in the Implementing Rules on Network Services.

EXAMPLE 1 Through the Get Spatial Objects function, a download service can either download a pre-defined data set or pre-defined part of a data set (non-direct access download service), or give direct access to the spatial objects contained in the data set, and download selections of spatial objects based upon a query (direct access download service). To execute such a request, some of the following information might be required:

- the list of spatial object types and/or predefined data sets that are offered by the download service (to be provided through the Get Download Service Metadata operation),
- and the query capabilities section advertising the types of predicates that may be used to form a query expression (to be provided through the Get Download Service Metadata operation, where applicable),
- a description of spatial object types offered by a download service instance (to be proviced through the Describe Spatial Object Types operation).

EXAMPLE 2 Through the Transform function, a transformation service carries out data content transformations from native data forms to the INSPIRE-compliant form and vice versa. If this operation is directly called by an application to transform source data (e.g. obtained through a download service) that is not yet conformant with this data specification, the following parameters are required:
Input data (mandatory). The data set to be transformed.

- Source model (mandatory, if cannot be determined from the input data). The model in which the input data is provided.
- Target model (mandatory). The model in which the results are expected.
- Model mapping (mandatory, unless a default exists). Detailed description of how the transformation is to be carried out.

DS Requirement 4	Data conformant to the application schema(s) defined in section 5.2 shall be encoded using the encoding(s) specified in this section.

Recommendation 7	It is recommended that also the encodings specified in this section be provided for the relevant application schemas.

9.2 Encodings

9.2.1 Default Encoding(s)

9.2.1.1. Default encoding for application schema <application schema name>

Format name: <name of the application schema> GML Application Schema
Version of the format: <version of the GML Application Schema>, GML, version 3.2.1
Reference to the specification of the format: ISO 19136:2007
Character set: UTF-8

The GML Application Schema is distributed in a zip-file separately from the data specification document.

10 Data Capture

There is no specific guidance required with respect to data capture.

11 Portrayal

This clause defines the rules for layers and styles to be used for portrayal of the spatial object types defined for this theme.

In section 11.1, the *types* of layers are defined that are to be used for the portrayal of the spatial object types defined in this specification. A view service may offer several layers of the same type, one for each dataset that it offers on a specific topic.

Section 11.2 specifies the default styles to be used for each of these layer types, while section 11.3 specifies other well-defined styles.

Where XML fragments are used in these sections, the following namespace prefixes apply:
- sld="http://www.opengis.net/sld" (WMS/SLD 1.1)
- se="http://www.opengis.net/se" (SE 1.1)
- ogc="http://www.opengis.net/ogc" (FE 1.1)

IR Requirement 10	If an INSPIRE view services supports the portrayal of data related to the theme *Geology*, it shall provide layers of the types specified in this section.

DS Requirement 5	If an INSPIRE view network service supports the portrayal of spatial data sets corresponding to the spatial data theme *Geology*, it shall support the default styles specified in the tables in this section. If no user-defined style is specified in a portrayal request for a specific layer to an INSPIRE view service, the default style specified in this section for that layer shall be used.

DS Requirement 6	If an INSPIRE view service supports the portrayal of spatial data sets corresponding to the spatial data themes *Geology*, apart from the default styles specified in Section 11.2, it shall also support the well-defined styles specified in this section.

11.1 Layer types for the spatial data theme *Geology*

Layer Type	Layer Title	Spatial object type(s)
GE.GeologicUnitsLithology	Geologic Units	GeologicUnit
GE.GeologicStructuresType	Geologic Structures	GeologicStructure
GE.GeomorphologicFeatureType	Geomorphologic Features	GeomorphologicFeature
GE.Geophysics. GeophStation	Geophysical Station	GeophStation
GE.Geophysics. GeophProfile	Geophysical Profile	GeophProfile
GE.Geophysics. GeophMeasurement3D	3D Geophysical Measurement	GeophMeasurement3D
GE.Geophysics. GeophCurveModel	Curve Model	CurveModel
GE.Geophysics. GeophSurfaceModel	Surface Model	SurfaceModel
GE.Geophysics. Geoph.SolidModel	Solid Model	SolidModel
GE.Geophysics. GeophSurvey	Geophysical Survey	GeophSurvey
GE.Aquifers	Aquifers	Aquifer

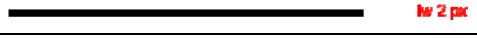
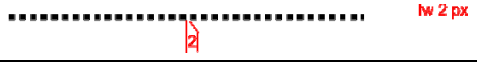
11.2 Default styles for the spatial data theme *Geology*

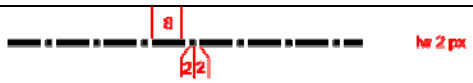
The polygons (MappedFeatures) of **Geologic Units** are only portrayed by colours related to the property Lithology. A proposal is to define the colour with the 3 numbers (Red, Green, Blue):

Extract:

	Term	ID	urn:cgi:classifierScheme:CGI:SimpleLithology:201001:	Red	Green	Blue
2	Alkali feldspar rhyolite	alkali_feldspar_rhyolite	urn:cgi:classifierScheme:CGI:SimpleLithology:201001:alkali_feldspar_rhyolite	206	170	242
3	Alkali olivine basalt	alkali-olivine_basalt	urn:cgi:classifierScheme:CGI:SimpleLithology:201001:alkali-olivine_basalt	115	51	230
4	Amphibolite	amphibolite	urn:cgi:classifierScheme:CGI:SimpleLithology:201001:amphibolite	76	173	119
5	Andesite	andesite	urn:cgi:classifierScheme:CGI:SimpleLithology:201001:andesite	148	74	235
6	Anorthositic rock	anorthositic_rock	urn:cgi:classifierScheme:CGI:SimpleLithology:201001:anorthositic_rock	247	173	198
7	Anthracite	anthracite_coal	urn:cgi:classifierScheme:CGI:SimpleLithology:201001:anthracite_coal	191	191	191
8	Aplite	aplite	urn:cgi:classifierScheme:CGI:SimpleLithology:201001:aplite	255	204	51

The lines (MappedFeatures) of **Geologic Structures** are portrayed by type. A proposal from is: Fault types (only coloured in black):

1GE ID	1GE Term	Draw annotation	Symbol [lw = line width in pixel]
ft	**fault**		
ft1	**strike slip fault**		
ft1.1	**dextral strike-slip fault**		
ft1.2	**sinistral strike-slip fault**		
ft2	**reverse fault (no dip)**	*Symbols in the upthrown block. (For cartographers: The line should be drawn so that the upthrown block is to the right in the drawing direction.)*	
ft2.1	**thrust fault**	*Symbols in the upthrown block. (For cartographers: The line should be drawn so that the upthrown block is to the right in the drawing direction.)*	
ft2.2	**high angle reverse**	*Symbols in the upthrown block. (For cartographers: The line should be drawn so that the upthrown block is to the right*	

		in the drawing direction.)	
ft3	**normal fault (no dip)**		
ft3.1	**low-angle normal fault**	*Symbols in the downthrown block. (For cartographers: The line should be drawn so that the downthrown block is to the right in the drawing direction*	
ft3.1.1	**detachment fault**	*Symbols in the downthrown block. (For cartographers: The line should be drawn so that the downthrown block is to the right in the drawing direction*	
ft3.2	**high-angle normal fault**	*Symbols in the downthrown block. (For cartographers: The line should be drawn so that the downthrown block is to the right in the drawing direction*	
ft4	**oblique slip fault**		

For Geophysics:

Considering the geometry of the three main geophysical classes (measurement, model, survey) 7 layers are theoretically enough to present any kind of geophysical features. There are three layers for measurements including stations, profiles and 3D measurements, three layers for models including curve model, surface model and solid model, and one layer for survey polygons. (In portraying only the bounding geometry is used, and for this reason discrete and grid models are not separated.) Unfortunately, the fact that geophysical features can be three dimensional complicates the situation. A geophysical profile – a line feature – can be vertical (borehole logging) and in this case it appears on the map as a point. Similarly, a surface model can be vertical (seismic section) and shown on the map as a curve. The ambiguity can be eliminated if further subclasses are defined on the basis of the method that is used. Taking into account the number of items in the limited code list of the core model 23 layers can be identified. The extended model could contain several times more. This seems to be too many for default layers. A reasonable compromise could be to reduce the size of the list by using only 11 categories that are most common in practice. (column "layer name2" in the table below)

Feature	Feature	layer name	layer name2	map geometry
GeophMeasurement	**GeophStation**	gravityStation	station	Point
		magneticStation		Point
	GeopProfile	flightLine	Profile	Curve
		seismics2D		Curve
		boreholeLogging	borehole logging	Point
	GeophMeasurement3D	seismics3D	3D measurement	Polygon
GeophModel	**CurveModel**	borholeLog	borehole log	Point
		layerModel	layer model	Point
		curveModel		Curve
	SurfaceModel	verticalSection	verticalSection	Curve
		horizontalSection	horizontalSection	Polygon
	SurfaceGridModel	verticalGrid	verticalSection	Curve
		seismicDepthSection		Curve
		horizontalGrid	horizontalSection	Polygon
		seismicDepthHorizon		Polygon
	SolidModel	solidModel	solidModel	Polygon
	SolidGridModel	solidGridModel	SolidModel	Polygon
		seismicBlock		Polygon
GeophSurvey		Gravimetry	Survey	Polygon
		Magnetometry		Polygon
		AirborneGeophysics		Polygon
		Seismics		Polygon
		BoreholeLogging		polygon

11.3 Other Well-defined Styles for the spatial data theme *Geology*

None.

11.4 Layers organisation

None.

Bibliography

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[DS-D2.5] INSPIRE DS-D2.5, Generic Conceptual Model, v3.1, *http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.5_v3.1.pdf*

[DS-D2.6] INSPIRE DS-D2.6, Methodology for the development of data specifications, v3.0, *http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.6_v3.0.pdf*

[DS-D2.7] INSPIRE DS-D2.7, Guidelines for the encoding of spatial data, v3.0, *http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.7_v3.0.pdf*

[ISO 19101] EN ISO 19101:2005 Geographic information – Reference model (ISO 19101:2002)

[ISO 19103] ISO/TS 19103:2005, Geographic information – Conceptual schema language

[ISO 19107] EN ISO 19107:2005, Geographic information – Spatial schema (ISO 19107:2003)

[ISO 19108] EN ISO 19108:2005 Geographic information - Temporal schema (ISO 19108:2002)

[ISO 19111] EN ISO 19111:2007 Geographic information - Spatial referencing by coordinates (ISO 19111:2007)

[ISO 19115] EN ISO 19115:2005, Geographic information – Metadata (ISO 19115:2003)

[ISO 19118] EN ISO 19118:2006, Geographic information – Encoding (ISO 19118:2005)

[ISO 19135] EN ISO 19135:2007 Geographic information – Procedures for item registration (ISO 19135:2005)

[ISO 19139] ISO/TS 19139:2007, Geographic information – Metadata – XML schema implementation

[OGC 06-103r3] Implementation Specification for Geographic Information - Simple feature access – Part 1: Common Architecture v1.2.0

Delete any of these references or add further references as applicable.

Annex A
(normative)

Abstract Test Suite

Any dataset conforming to this INSPIRE data specification shall meet all requirements specified in this document.

NOTEA common abstract test suite including detailed instructions on how to test each requirement will be added at a later stage.

Annex B
(informative)

Use Cases for Geology and Aquifers

Annex B*B.1 Introduction*
This document is a collection of use cases for Geology and Mineral Resources defined from the analysis of Examples of use.

B.2 Use cases for Geology
Geological information is mainly collected or produced to be used by other thematic domains (geo-hazard assessment, ensuring safe disposal of wastes, providing construction material, …) as described in the document "Examples of use".

B.2.1 UC01: Providing geological data to detect geo-hazards
This use case is related to example of use:
- GE-02: Detecting geo-hazards.

B.2.1.1 Overview and involved actors
This use case is a part of a more general use case which provides risk maps in a process that involves many other data than geological data (like meteorological data, elements at risk, …) in the disaster management cycle.
The goal of this use case is therefore to deliver geological data to the engineer responsible for establishing risk maps.

Actors:
- Geological surveys to provide geological information (Geological Surveys represent the Member States)
- Engineers responsible for establishing risk maps using the geological information in combination with other data.

B.2.1.2 Narrative description
The hazard is often defined as the probability of occurrence of a potentially damaging phenomenon within a given area and a given period of time. To define this probability the engineer has to access data describing the physical, chemical, mechanical properties of rocks.

B.2.1.3 Detailed description

Use case description	
Name	Providing geological data to detect geo-hazards
Priority	High
Description	The user selects the relevant geographic area and search for geological data: geological map, borehole data, and geotechnical data.
Pre-condition	Geological data are available in line with INSPIRE specifications. A specific vocabulary related to the user requirements is

	available with a “mapping” between geological terms and user’s terms (done by the data provider?).
Flow of events – Basic path	
Step 1	The user selects on a geo-portal the area of interest and search in a metadata catalogue for geological maps with lithological and structural information.
Step 2	The user displays the geological map and accesses detailed information about the geologic units (lithology) and structures (existing faults)
Step 3	The user searches in a metadata catalogue for borehole data with information about geologic unit thickness and depth, water level, physical and chemical properties
Step 4	The user accesses the borehole data to get the values of the properties.
Step 5	The user searches in a metadata catalogue for geotechnical data related to the area (existing measurements), or geotechnical properties related to the lithology in general.
Step 6	The user accesses the geotechnical data to get the values of the properties.
Flow of events – Alternative path	
Post-conditions	
Post-condition	The user has a set of geological data related to the selected area.
Data source: *INSPIRE-conformant Geology data set provided by Member Sate*	
Description	Geological data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	Scale relevant to the application (tbd)
Delivery	INSPIRE Geology GML Application schema
Documentation	INSPIRE Geology Data Specification

B.2.1.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

Geological units with:
- their related polygons
- lithology

Geologic structures (faults) with:
- their related lines
- attribute: active or non-active

Borehole data with:
- geologic unit thickness and depth
- water level
- any other properties (physical and chemical) measured

Geotechnical data with:
- data related to the geologic units (from measurements: porosity, …)
- or values related to the rock types in general

B.2.1.5 Relationship with other INSPIRE Themes

This use case has some relationships with the following INSPIRE data themes:

- Soils: the geotechnical properties are those of the rocks but also of the soil on a “continuous column”.
- Natural Risk Zones: Geology is a provider of information about underground to engineers who has to define the risk zones.

B.2.2 UC02: Providing geological data to ensure safe disposal of waste

This use case is related to example of use:

- GE-03: Ensuring the safe disposal of wastes, Nuclear Waste, Carbon Capture and Storage.

B.2.2.1 Overview and involved actors

This use case is a part of a more general use case which provides geological data in a process that involves many other data than geological data (like population distribution, land use …) in the waste disposal management cycle. It is relevant for the disposal of many different kinds of waste in various geological environments. The goal of the use case is to deliver geological data to the authorities and companies responsible for safe disposal of waste.

Actors:

- Geological surveys to provide geological data (Geological Surveys represent the Member States)
- Authorities and companies responsible for safe disposal of waste using the geological data in combination with other data.

B.2.2.2 Narrative description

“Safe disposal” usually means that the waste is placed in the bedrock or in unconsolidated superficial deposits at some depth (< 2 500 meters) below the surface. Depending on the nature of the waste the actual site of disposal is either in a natural space (e.g. pore space) or in man-made space (e.g. excavation or bore hole). Examples of waste are burned nuclear fuel and carbon dioxide. Geological data is needed to build a 3D-model that is used and refined during all stages of the waste disposal process: site selection, planning, characterization, construction, and follow-up program.

B.2.2.3 Detailed description

Use case description	
Name	Providing geological data to ensure safe disposal of waste
Priority	High
Description	The user selects the relevant geographic area and searches for geological data from the surface and underground: geological map, borehole data, groundwater data, geophysical and geochemical data.
Pre-condition	Geological data are available in line with INSPIRE specifications.
Flow of events – Basic path	
Step 1	The user selects on a geo-portal the area of interest and searches in a metadata catalogue for geological maps with lithological and structural information.
Step 2	The user displays the geological map and accesses detailed information about the geologic units (lithology etc) and structures (existing faults)

Step 3	The user searches in a metadata catalogue for mineral resource data with information about location of known mineral deposits
Step 4	The user displays the mineral resource data and accesses detailed information about the deposits
Step 5	The user searches in a metadata catalogue for geophysical data with information about seismicity and survey data
Step 6	The user displays the geophysical data and accesses detailed information about the geophysical expression of the rocks
Step 7	The user searches in a metadata catalogue for borehole data with information about geologic unit thickness and depth, water level, physical and chemical properties, fracture properties
Step 8	The user accesses the borehole data to get the values of the properties.
Step 9	The user searches in a metadata catalogue for groundwater data with information about groundwater flow and groundwater chemistry
Step 10	The user accesses the groundwater data to get the values of the properties.
Flow of events – Alternative path	
Post-conditions	
Post-condition	The user has a set of geological data for 3D-modelling of the selected area.
Data source: *INSPIRE-conformant Geology data set provided by Member Sate*	
Description	Geological data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	National to local
Delivery	INSPIRE Geology GML Application schema
Documentation	INSPIRE Geology Data Specification

B.2.2.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

Geological units with:
- their related spatial objects
- lithology, mineralogical composition, chemical composition, age, contact relationships, alteration

Geologic structures (faults) with:
- their related spatial objects
- attribute: active or non-active

Mineral resource data
- location of mineral deposits

Geophysical data
- seismicity
- survey data (magnetic, electromagnetic, gravity, elevation)

Borehole data with:

- location of bore holes
- geologic unit thickness and depth
- water level
- mineralogical and chemical composition of rocks
- porosity, permeability, temperature, fracture pressure, capillary pressure
- fracture frequency, fracture fillings

Groundwater data
- location of wells
- groundwater flow
- groundwater chemistry

B.2.2.5 Relationship with other INSPIRE Themes

This use case some relationships with the following INSPIRE data themes.

- Environmental monitoring facilities: Aquifer monitoring stations, seismicity networks
- Protected sites: Groundwater protection
- Elevation: Digital elevation models

B.2.3 UC03: Providing geological data to detect ground instability in a flat area

This use case is related to example of use:
– GE-02: Detecting geo-hazards.

B.2.3.1 Overview and involved actors

This use case is a very particular case which provides risk maps in a process that involves many other data than geological data (like use of the subsurface data, elements at risk…) in the land and urban management cycle.

The goal of this use case is to deliver geological data to the responsible for land and urban planning. These data should then be merged with other related data, in order to construct a basic framework which allows classifying areas according to its hazard and risk levels. From this, further specific works, at the scale of the project, should be developed.

Actors:
- Geological surveys to provide geological information, including hazard assessment, if available (Geological Surveys represent the Member States)
- Mining Authorities to provide information on active and abandoned underground activities
- Geological Surveys and/or Water Authorities to provide information on groundwater
- Responsible for establishing risk maps using the geological information in combination with other data.
- Land and urban planners

B.2.3.2 Narrative description

Land and urban planning need to know the ground stability for safe infrastructure development.

In flat areas, ground instabilities are mainly related to:

- The existence of soluble lithologies in the subsurface (i.e. evaporites: gypsum or salt; carbonates…)
- The existence of sand and gravel deposits, loess, peat, shrinking and swelling clays, and other unconsolidated materials, including artificial landfills.
- The variations in the water table (natural and induced by artificial activities)
- The existence of a (melting) permafrost

- The presence of mining, gas production, subsurface infrastructures and other anthropic underground structures, both active and abandoned
- The seismic activity

Some surface features, as are dolines, some kind of depressions, or other landforms, can be indications of ground instability.

The three first groups of data (lithologies, unconsolidated deposits and hydrogeological data) and the surface features indicating ground instability (geomorphological elements) are geological data and the rest are related data.

(The hazard is often defined as the probability of occurrence of a potentially damaging phenomenon within a given area and a given period of time. To define this probability the engineer (?) has to access data describing the physical, chemical, mechanical properties of rocks).

B.2.3.3 Detailed description

Use case description	
Name	Providing geological data to detect ground stability in a flat area
Priority	High
Description	The user views the geographic work area and search for geological data (geological map, borehole data, geotechnical data) and other related data (presence of mining, gas production, subsurface infrastructures and other anthropic underground activities, both active and abandoned; presence of permafrost; seismological zoning)
Pre-condition	Geological and the other related data are available in line with INSPIRE specifications. A specific vocabulary related to the user requirements is available with a “mapping” between geological terms and user’s terms (done by the data provider).
Flow of events – Basic path	
Step 1	The user selects on a geo-portal the area of interest and search in a metadata catalogue for geological maps with lithological, structural and geomorphological information.
Step 2	The user displays the geological map and accesses detailed information about the geologic units (rock type, including unconsolidated natural materials and anthropogenic deposits or landfills), the landforms (indices of collapse structures), hydrogeological (watertable) and tectonic structures (existing faults)
Step 3	The user searches in a metadata catalogue for borehole data with information about geologic unit thickness and depth (including artificial landfills), water level, physical and chemical properties
Step 4	The user accesses the borehole data to get the values of the properties.
Step 5	The user searches in a metadata catalogue for geotechnical data related to the area (existing measurements), or geotechnical properties related to the materials in general.
Step 6	The user accesses the geotechnical data to get the values of the properties.
Step 7	The user downloads all the selected information to his computer and makes a specific map of the work area
Flow of events – Alternative path	

Post-conditions	
Post-condition 1	The user has a set of geological data related to the selected area (a specific geological map).
Post-condition 2	The same user (or a different user involved in the land and urban management) merges the geological information with the other related data and constructs a map which will be the basis for further specific, on site works, at the scale of the project.
Data source: *INSPIRE-conformant Geology and other related data set provided by Member Sate*	
Description	Geological and other related data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	Scale relevant to the application (tbd)
Delivery	INSPIRE Geology GML Application schema
Documentation	INSPIRE Geology Data Specification

B.2.3.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

Geological units, including artificial unconsolidated deposits, with:
- their related polygons
- lithology

Geologic structures (contacts (primary = original, and secondary = mechanical: faults) with:
- their related lines
- their related indications of dip and dip direction
- landforms (collapse structures, dolines)
- attribute: active or non-active

Borehole data with:
- geologic unit thickness and depth
- water level
- any other properties (physical and chemical) measured

Geotechnical data with:
- data related to the geological units (from measurements: porosity, …)
- or values related to the rock types in general

B.2.3.5 Relationship with other INSPIRE Themes

This use case has some relationships with the following INSPIRE data themes:
- Soils: the geotechnical properties are those of the rocks but also of the soil on a “continuous column”.
- Natural Risk Zones: Geology is a provider of information about underground to engineers who have to define the risk zones.
- Energy
- Several aspects from Annex I

B.2.4 UC04: Looking for deep fractured zones in the basement (Geothermal exploration)

This use case is related to example of use:

- GE-12: Use of geophysics.

B.2.4.1 Overview and involved actors

This use case is part of a more general use case of providing access to public geophysical information for users interested in mineral or geothermal exploration.
The goal of this use case is to demonstrate the interoperability between geological, borehole and geophysical data services.

Actors:

- Geological surveys to provide geological information
- Geophysicists responsible for establishing
- Geothermal exploration company (user)

B.2.4.2 Narrative description

.
In order to find an optimum location for a geothermal drilling the user is looking for data resources related to deep fractured zones in a specific geological unit. Borehole locations are identified in a GIS search and then a specific borehole is selected. From the list of geological units crossed by the borehole the one related to the carboniferous basement is selected and the related observations are examined. From the observation results a geophysical resistivity cross section is selected. If it is freely available the user can download the online resource, otherwise the distributor is contacted and the data is purchased.

B.2.4.3 Detailed description

Use case description	
Name	Looking for deep fractured zones in the basement
Priority	High
Description	
Pre-condition	Geological data are available in line with INSPIRE specifications.
Flow of events – Basic path	
Step 1	The user selects „**borehole**" from the **catalogue of available features** on the geoportal.
Step 2	Starts a BBOX search for boreholes in the target area
Step 3	Locates a borehole and opens it
Step 4	Identifies a **geologicUnit** from the list of **features of interest** and opens it. (basement)
Step 5	Selects a **physical property** (conductivity) of the geologicalUnit and opens the list of related **observations**
Step 6	The results of the selected observation is a **geophysical model** (2D MT conductivity profile showing the resistivity variations of the basement)
Step 7	The user opens the coverage in a 3D viewer
Flow of events – Alternative path	
Step 7	The user checks the **distribution metadata** of the model and finds the link to the data provider
Step 8	Data provider is contacted and the results are purchased
Post-conditions	
Post-condition	

Data source: *INSPIRE-conformant Geology data set provided by Member Sate*	
Description	Geological data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	Scale relevant to the application (tbd)
Delivery	INSPIRE Geology GML Application schema
Documentation	INSPIRE Geology Data Specification

B.2.4.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

Borehole data with:
- geologic unit thickness and depth
- water level
- any other properties (physical and chemical) measured

Geological units crossed by the borehole with:
- their physical properties (conductivity) and related observations

Geophysical objects:
- geophysical method type, location, distribution metadata
- geophysical cross section, online resource, distribution metadata

B.2.4.5 Relationship with other INSPIRE Themes

This use case has some relationships with the following INSPIRE data themes:
- Mineral resources – for exploration
- Energy resources – for the Geothermal potential

B.2.5 UC05: Checking background radiation level changes

This use case is related to example of use:
- GE-12: Use of geophysics.

B.2.5.1 Overview and involved actors

This use case is part of a more general use case of providing access to public geophysical information for users interested in the physical state of environment and the impact of industrial contaminations. The goal of this use case is to demonstrate the importance of access to geophysical monitoring data in order to locate large areas affected by possible radioactive contamination.

Actors:
- Environment agency (user)
- Geophysicists responsible for establishing

B.2.5.2 Narrative description

After a nuclear power plant accident an environment agency analyses the impact of the possible radioactive contamination and collects information on the changes of background radiation intensity. The INSPIRE geoportal is used to locate airborne geophysical surveys that acquired total gamma radiation data over large areas before and after the accident. The results are compared and the areas showing significant changes are outlined for further inversitation.

B.2.5.3 Detailed description

Use case description	
Name	Checking background radiation level changes
Priority	High
Description	
Pre-condition	Geological data are available in line with INSPIRE specifications.
Flow of events – Basic path	
Step 1	The user starts a BBOX search for airborne **geophysical surveys** carried out before the accident in the target area
Step 2	The user locates a survey and checks the measured **physical parameters**
Step 3	If the list of physical parameters include total gamma radiation the user checks the **distribution metadata** of the model and finds the link to the data provider
Step 4	The user starts a BBOX search for airborne **geophysical surveys** carried out after the accident in the target area
Step 5	The user locates a survey and checks the measured **physical parameters**
Step 6	If the list of physical parameters include total gamma radiation the user checks the **distribution metadata** of the model and finds the link to the data provider
Step 7	Data provider is contacted and the results are purchased
Step 8	Radiation maps are compared and anomalous areas are selected for further investigation
Post-conditions	
Post-condition	
Data source: *INSPIRE-conformant Geology data set provided by Member Sate*	
Description	Geological data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	Scale relevant to the application (tbd)
Delivery	INSPIRE Geology GML Application schema
Documentation	INSPIRE Geology Data Specification

B.2.5.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

Geophysical Survey:

- geometry, geophysical method type (airborne geophysics), list of measured physical parameters (total gamma radiation)
- distribution metadata

B.2.5.5 Geophysical features

From the use cases there is a request for three main types of geophysical features. These are:

- **Geophysical measurement**
- **Geophysical model**
- **Geophysical survey**

Geophysical measurement

Geophysical measurements are used to collect information on the boundary of the observed features. According to the geometry of their sampling characteristics three subtypes has to be defined: stations, profiles and 3D measurements.

- Station (sampling point). Examples: magnetic station, gravity station, vertical electric sounding, seismology monitoring station, magnetotelluric station, etc.
- Profile (sampling curve). Examples: seismic profile, flight line, borehole log, multielectrode DC profile, etc.
- 3D measurment (sampling surface). Examples: 3D seismics, 3D multielectrode measurements (DC tomography), etc.

Measurement data itself is subject of analysis done by experts, and therefore it is not in the scope of INSPIRE. Important attributes of geophysical measurements are location, geometry, geophysical method type, and metadata, especially distribution information.

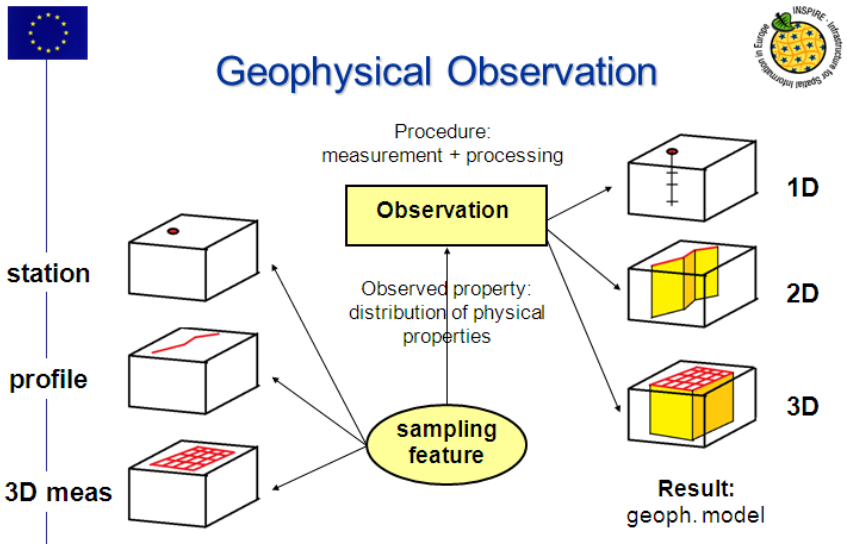


figure 1. Geophysical features and the O&M model

Geophysical model

Geophysical models are results of processing data collected by geophysical measurements. Models represent spatial distribution of physical parameters within the observed feature, and can be described as standard coverages. According to their spatial characteristics the following subtypes has to be defined:

Discrete models:

- Curve model (discrete curve coverage). Example: geoelectric layer model
- Surface model (discrete surface coverage). Example: horizontal and vertical cross sections, (cross section of geoelectric layers)
- Solid model (discrete solid coverage). Example: a conductive 3D body in a resistive host

Discrete grid models:

- Surface grid model (2D grid coverage) Example: cross sections, depth horizons, (seismic depth section, resistivity cross section)
- Solid grid model (3D grid coverage) Example: seismic 3D block, DC tomography

Geophysical processing is an observation through sampling, where the sampled feature is the measured data, the result is the distribution of the observed property. We can also say that the

sampled feature is the earth, because the result contains earth properties at the sampling locations (figure 1.).

Geophysical survey

Geophysical exploration surveys may include large number of measurements over large areas. The individual measurements may not be important for the user, but the existence, type, and availability of their results are essential. Surveys are defined as polygon features with the most important attributes of the related survey, like geophysical method types, measured physical properties metadata, especially distribution information.

B.2.5.6 Relationship with other INSPIRE Themes

This use case has some relationships with the following INSPIRE data themes:

- Human health – for identifying areas with different level of hazard caused by increased background radiation intensity
- Natural risk zones – to register hazardous areas with increased background radiation intensity

B.2.6 UC06: Providing data to undertake water balance to ensure compliance with the WFD

This use case is related to example of use:
- AQ-01: Water supply (water abstraction).

B.2.6.1 Overview and involved actors

The goal of this use case is therefore to deliver hydrogeological data to professionals responsible for establishing whether groundwater bodies are over or under abstracted according to the WFD. Examples of the professionals include regulators such as the Environment Agency of England and Wales.
Actors:

- Geological surveys to provide geological information (Geological Surveys represent the Member States)
- Other hydrometric organizations to provide relevant hydrological data, e.g. rainfall
- Professionals responsible for ensuring compliance with the WFD, e.g. regulator in each member state.
- Professionals responsible for establishing water supply system, for local government to support water management decision process as well as individual investors.
- Water modelers.

B.2.6.2 Narrative description

The WFD requires that a groundwater body has “good status” in that it is not over abstracted. In order to ensure that a groundwater body is not over abstracted, then a water balance needs to be undertaken. The various inputs and outputs to the system need to be quantified and the balance calculated. Importantly the proportion of abstraction compared to recharge to the aquifer has to be determined. The water balance is created for an Assessment Point (AP) for each sub-catchment.

B.2.6.3 Detailed description

Use case description	
Name	Providing data to undertake water balance to ensure compliance with the WFD
Priority	High
Description	The user selects the relevant geographic area and searches for hydrogeological and hydrological data: abstraction, baseflow,

	springflow, rainfall, potential evaporation.
Pre-condition	Hydrogeological and hydrometric data are available in line with INSPIRE specifications. A specific vocabulary related to the user requirements is available with a “mapping” between hydrogeological terms and user’s terms.
Flow of events – Basic path	
Step 1	The user selects on a geo-portal the area of interest and searches in a metadata catalogue for hydrogeological maps and other relevant hydrological data.
Step 2	The user displays the hydrogeological map and accesses detailed information about the groundwater resources location (useful groundwater aquifers) and hydrogeological parameters (potential discharge of the well, drawdown)
Step 3	The user searches in a metadata catalogue for relevant hydrological data.
Step 4	The user accesses the hydrological data to get the values of the properties and combines them with the hydrogeological data to perform a water balance for the required AP.
Step 5	The user uploads the water balance back into a portal to provide information at the AP.
Flow of events – Alternative path	
Post-conditions	
Post-condition	The user has a set of hydrogeological and hydrometric data related to the selected area as well as a water balance for the relevant AP.
Data source: *INSPIRE-conformant Geology data set provided by Member Sate*	
Description	Hydrogeological and hydrological data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	Scale relevant to the application (tbd)
Delivery	INSPIRE Geology GML Application schema
Documentation	INSPIRE Geology Data Specification

B.2.6.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

Hydrogeological units with:
- their related polygons
- potential discharge
- water table depth
- aquifer type
- rock lithology

Well data in relation to borehole with:
- geologic unit thickness and depth
- water level
- any other properties (physical and chemical) measured

Generally to create water balance two main information are needed:
- Recharge (rainfall, river infiltration, river vanish point)

- Discharge – groundwater abstraction (water well, effluent stream, spring or seep)

Vanishing point, spring and seep are objects of interest in Hydrography DS (Annex I)

B.2.6.5 Relationship with other INSPIRE Themes

This use case has some relationships with the following INSPIRE data themes:
- Hydrology: HydroPointOfInterest
- Geology: the geologic property of an aquifer

Groundwater Unit is an object in GWML in relation to Geologic Unit in GeoSciML. Although to describe aquifer the more precise information is expected. The GWML object structure may be use as pointed at figure bellow (pink). Those object allow to define type aquifer water table (confined, unconfined).

B.2.7 UC07: Groundwater reporting for WFD

This use case is related to example of use:
- AQ-05: Groundwater quality and quantity assessment.

B.2.7.1 Overview and involved actors

The implementation of the WFD requires the handling of spatial data both for the preparation of the River Basin Management Plans and for the reporting to the Commission.
Article 15 of the Water Framework Directive (WFD) requires Member States to provide information to the European Commission concerning the river basin management plans (RBMP). The RBMP covers, among others a general description of the characteristics of the river basin district (RBD) required under Article 5 and Annex II WFD including the mapping of the location and boundaries of groundwater bodies (GWB) (Annex VII, WFD).
Recommendation for the form and scope of spatial information deliver under the WFD and the Groundwater Directive (GWD) were presented in "Updated Guidance on Implementing the Geographical Information System (GIS) Elements of the EU Water policy".
Member States are obliged to deliver necessary data to fulfill Water Information System of Europe (WISE) managed by European Environmental Agency (EEA).

Actors:
- Geological surveys to provide geological information (Geological Surveys represent the Member States)
- Member States Environmental Agencies or other bodies responsible for reporting
- European Environmental Agencies (EEA)

B.2.7.2 Narrative description

GWBs according to Article 2.12 WFD are defined as "a distinct volume of groundwater within an aquifer or aquifers". Thus GWBs are three-dimensional. For the time being it is not possible to represent WBs three-dimensionally in geographic information systems as there are, in most cases, not enough data available to develop three-dimensional models of GWBs. Thus the representation of the feature will be as two-dimensional polygons.

The spatial data concerning GWB is a basis for general maps produce:
- Map 1: Quantitative status – Identification of bodies that are at "good quantitative status" and those that are at "poor quantitative status";
- Map 2: Achievement/exceedance of standard for nitrates (value in Annex 1 of GWD or set according to paragraph 3 of Annex 1 GWD, and according to status assessment procedure in Article 4 of GWD);
- Map 3: Achievement/exceedance of standard for pesticides (combined total and individual value in Annex 1 of GWD or set according to paragraph 3 of Annex 1 GWD, and according to status assessment procedure in Article 4 of GWD);
- Map 4: Achievement/exceedance of threshold values set by Member States for other pollutants (considering in this category the list of substances as contained in Part B of Annex II of GWD and

more generally any other pollutants contributing to the characterisation of groundwater bodies as being 'at risk', and according to status assessment procedure in Article 4 of GWD);
- Map 5: Trends - Identification of: (a) groundwater bodies with environmentally significant and sustained upward trends in pollutant concentrations, and (b) groundwater bodies in which trends have been reversed;

GIS data submitted by Member States will be also used to produce a **WISE Reference GIS dataset of groundwater bodies** by the EEA or its contracted partners.
GWBs provided by Member States will be merged into one dataset taking into account the description of the submitted GWBs (layered, depth range, aquifer type etc.) to produce a consistent dataset.

B.2.7.3 Detailed description

Use case description	
Name	Providing groundwater data to WISE reporting
Priority	High
Description	The Member States are obliged to deliver Groundwater Bodies and Groundwater monitoring information to European Environment Agency (EEA) for Water Management Plans
Pre-condition	Hydrogeological data are available in line with INSPIRE specifications. The Reporting schema provide a framework for water related reporting(Water Framework Directive). Format of reporting sheets is defined in Water Information System for Europe (WISE) hosted by EEA
Flow of events – Basic path	
Step 1	The user selects on a geo-portal the area of interest and search in a metadata catalogue for groundwater maps with groundwater bodies.
Step 2	The user displays the groundwater map and accesses detailed information about the groundwater bodies (status) and monitoring stations (quality and quantity)
Step 3	The user searches in a metadata catalogue for groundwater monitoring station data with information about aquifer unit thickness and depth, water level, physical and chemical properties
Step 4	The user accesses the monitoring station data to get the values of the properties.
Flow of events – Alternative path	
	The user (EEA) selects on a geo-portal the area of interest and search in a metadata catalogue for groundwater maps with groundwater bodies and monitoring stations
	The user (EEA) displays the groundwater map and accesses detailed information about the groundwater bodies (status) and monitoring stations (quality and quantity)
Post-conditions	
Post-condition	The user has a set of groundwater data related to the selected area.
Data source: *INSPIRE-conformant Geology data set provided by Member Sate*	
Description	Groundwater data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	Scale relevant to the application (tbd)
Delivery	INSPIRE Geology GML Application schema

B.2.7.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

The following data were requested as a minimum to be provided for each GWB (under Reporting sheet GWB1):

- Unique code;
- Name (if available);
- X co-ordinate (Longitude) of the centroid of the GWB;
- Y co-ordinate (Latitude) of the centroid of the GWB; and
- Size (surface area (m_2), unique identifier for the horizon where separate overlying bodies exist and, if possible, volume of aquifer (m_3).

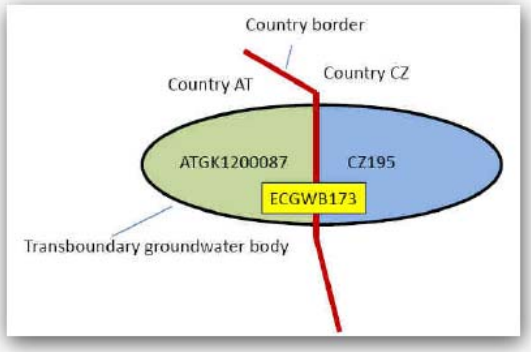
This was translated into the reporting schemas as follows:

Field	Data Type	Size	Obligation	Description
EU_CD	Text	42	mandatory	Unique code for GWB at European level
MS_CD	Text	40	mandatory	Unique code for the GWB within the MS
LAT	Text	9	mandatory	Latitude of the centre of the GWB in ETRS89 projection
LON	Text	9	mandatory	Longitude of the centre of the GWB in ETRS89 projection
AREA	Double		mandatory	GWB1: Total surface area of the water body in sq km
NAME	Text	100	optional	Locally used name for GWB
TRANSBOUNDARY	Text	1	optional	Does the groundwater body crass a country border
CAPACITY	Double		optional	Capacity of GWB in m3
HORIZON	Double		optional	Groundwater horizon when separate overlaying GWB exist
LAYERED	Text	1	optional	Indicator for groundwater bodies with deeper relevant layers 0 = no deeper layers 1 = deeper aquifer layers
OUT_OF_RBD	Text	1	optional	Indicator if any part of GWB falls outside RBD

In addition to the IDs assigned by Member States (MS_CD), unique IDs will be generated at EC level (EU_CD) to uniquely identify groundwater bodies in the WISE Reference GIS dataset. This is necessary to identify and visualise **transboundary GWBs**. With the IDs assigned by Member States only the Member State part of transboundary GWBs can be identified.

The structure of the WISE code will be defined by the data provider of the reference dataset according to the specifications given in the WISE GIS guidance document, second edition. The data provider will be the EEA or its contracted partner.

The following diagram illustrates a fictive example of MS GWB-IDs and European (WISE) GWBIDs for a transboundary groundwater body.



There is a transboundary GWB between AT and CZ. Both Member States delineate the national parts of the transboundary GWBs and assign IDs (EUGroundwaterBodyCode=ATGK1200087, CZ195). The boundaries of the GWB are harmonised at the country border and the GWBs are marked as transboundary. At EU level it will be identified which Member State parts of transboundary GWBs belong together and unique IDs for the total GWB will be assigned (ECGWB173).

To develop a more consistent picture of groundwater bodies it will be necessary to get information on aquifer types and the 3-dimensional characteristics of GWBs, as they might overlay each other.

GIS data to be reported for each groundwater body are specified in Guidance Document: Guidance for reporting under the Water Framework Directive (see Chapter 13). This data will allow the description and visualisation of GWBs and groups of GWBs. Furthermore the parameter horizon should also be characterised according to the groundwater body layer (e.g. alluvial deposit layer, “main” layer, deep horizon (cenoman), thermal or mineral water).

The definition of the parameter “**horizon**”, which will be used in the sense of the numerical position of groundwater body layer (e.g. 1 for the first horizon from the surface, 2 for the second horizon from the surface, 3 for the third horizon from the surface, 4 for fourth and deeper horizons from the surface).

The following attributes should be reported for each GWB

- Water body code
- Water body name
- Shape/GML file
  - Groundwaters: boundaries of all groundwater bodies or groups of groundwater bodies identified.
- For groundwater bodies or groups of groundwater bodies, if available:
  - Layered (Y/N)
  - Average depth to groundwater body (m)
  - Average thickness of groundwater body (m)
  - Assignment to a depth range where the main part of the GWB is situated in (depth ranges: 0-20m, 20-50 m, 50-200 m, >200m)
  - Directly dependent aquatic ecosysteRBD (Y/N)
  - Directly dependent terrestrial ecosysteRBD (Y/N)
  - Geological formation – aquifer type (according to a predefined typology)
  - Type of vertical orientation of GWB (indicated by category and visualised by symbols)
  - Volume of aquifer (m3) (if possible)
- Relevant point source discharges to groundwater
  - ID of significant point sources where data already available
  - Latitude and longitude of each relevant point source (if possible)
  - Type of point source (see GWPI3)
- Relevant diffuse source pollution to groundwater bodies
  - WB Affected? (Y/N)
  - Type of source (see GWPI4)
- Relevant abstractions from groundwater
  - WB Affected? (Y/N)
  - Latitude and longitude of each abstraction (if possible)
  - Type of abstraction (see GWPI5)
- Relevant artificial recharge of groundwater
  - WB Affected? (Y/N)
  - Type of Regulation/Alteration (see GWPI6)
- Significant saltwater or other intrusion

  - o WB Affected? (Y/N)
- Other pressures
  - o WB Affected? (Y/N)
  - o Type of Pressure (to be specified see GWPI8)
- Impacts
  - o Type of impact identified (see GWPI9)
- Protected areas
  - o Water body within or overlapping with a protected area (Y/N)
  - o Type of protected area (provide a shape file only where information is NOT reported under any other Directive. Where information has been provided under other Directives provide the unique identifier (code) of the appropriate protected area)

For WISE reporting it is expected that except the GroundWater bodies the Groundwater monitoring station location will be required for reporting.

B.2.7.5 Relationship with other INSPIRE Themes

This use case has some relationships with the following INSPIRE data themes:

- Hydrography (HY): GWB is a subset of Water Body class which is the main element in WFD directive reporting as well as base information for Water Management Plans analyzes (water balance)..
- Area management/restriction/regulation zones and reporting units (AM): there is a important relation between GWB and water related reporting units
- Environmental Monitoring Facilities (EF): location and characteristics of Groundwater monitoring facilities will be provided by EF specification, but the link to GW monitoring measurement method and properties is needed in Geology DS

B.2.8 UC08: Providing hydrogeological data to define significant pressure

This use case is related to example of use:

- AQ-04: Protecting ecosystems dependent on groundwater

B.2.8.1 Overview and involved actors

The goal of this use case is therefore to deliver hydrogeological data to professionals responsible for biological diversity

Actors:

- Geological surveys to provide geological information (Geological Surveys represent the Member States)
- Professionals responsible for biological diversity.
- Soil experts

B.2.8.2 Narrative description

Groundwater dependent ecosystems (GDE) are a diverse and important component of biological diversity. The term GDE takes into account ecosystems that use groundwater as part of survival, and can potentially include wetlands, vegetation, mound springs, river base flows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps. The groundwater dependence of ecosystems will range from complete reliance to those that partially rely on groundwater, such as during droughts. The degree and nature of dependency will influence the extent to which ecosystems are affected by changes to the groundwater system, both in quality and quantity. The EU Water Framework Directive (WFD) requires those terrestrial ecosystems dependent on groundwater be identified and the anthropogenic pressures acting on the ecosystems analysed.

B.2.8.3 Detailed description

Use case description	
Name	Managing the positive role aquifers play in supporting ecosystems
Priority	High
Description	The user selects the relevant geographic area and search for hydrogeological data: hydrogeological map (groundwater table level) and well data (geological profile) to estimate the risks associated with groundwater abstraction pressures on the condition of groundwater dependent ecological features.
Pre-condition	Hydrogeological data are available in line with INSPIRE specifications. A specific vocabulary related to the user requirements is available with a “mapping” between hydrogeological terms and user’s terms (done by the data provider?).
Flow of events – Basic path	
Step 1	The user selects on a geo-portal the area of interest and search in a metadata catalogue for hydrogeological maps with groundwater bodies information.
Step 2	The user displays the hydrogeological map and accesses detailed information about the groundwater bodies location, useful groundwater aquifers and hydrogeological parameters (potential discharge of the well, regional discharge pressures, drawdown)
Step 3	The user searches in a metadata catalogue for well data with information about geologic unit thickness and depth, water level changes, groundwater quality (physical and chemical properties)
Step 4	The user accesses the well data to get the values of the properties.
Flow of events – Alternative path	
Post-conditions	
Post-condition	The user has a set of hydrogeological data related to the selected area and is able to analyse data to provide information for decision makers.
Data source: *INSPIRE-conformant Geology data set provided by Member Sate*	
Description	Hydrogeological data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	Scale relevant to the application (tbd)
Delivery	INSPIRE Geology GML Application schema
Documentation	INSPIRE Geology Data Specification

B.2.8.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

Hydrogeological units with:

- their related polygons
- potential discharge
- water table depth
- rock lithology

The dependency of ecosystems on groundwater is based on some basic groundwater attributes :

- flow or flux - the rate and volume of supply of groundwater;
- level - for unconfined aquifers, the depth below surface of the water table;
- pressure - for confined aquifers, the potentiometric head of the aquifer and its expression in groundwater discharge areas;
- quality - the chemical quality of groundwater expressed in terms of pH, salinity and/or other potential constituents, including nutrients and contaminants.

B.2.8.5 Relationship with other INSPIRE Themes

This use case has some relationships with the following INSPIRE data themes:

- Bio-geographical Regions, Habitats and Biotopes, Species Distribution (BR, HB, SD): existence of some ecosystems in strong plant and animal communities relations with groundwater system.
- Geology (GE): the geologic property of an aquifer
- Soil (SO): changing soil moisture level can cause drought
- Sea region (SR): saline or other intrusion changing ecosystem condition
- Land Use (LU)

B.2.9 UC09: Providing data to assess Corrosivity to Underground Assets

This use case is related to example of use:
- AQ-07: Groundwater as a hazard

B.2.9.1 Overview and involved actors

The goal of this use case is therefore to deliver hydrogeological and geochemical data to professionals responsible for operating underground assets such as water pipes and building foundations to establish whether corrosion will occur and degrade the asset sufficient to cause a leakage, etc.
Actors:

- Geological surveys to provide geological information (Geological Surveys represent the Member States)
- Other organizations to provide relevant geochemical data, e.g. concentration of sulphates/sulphides.
- Professionals responsible for assessing risk of corrosivity to underground assets, i.e. pipeline operators, etc.

B.2.9.2 Narrative description

Underground assets, such as iron pipes, concrete foundations are at risk from corrosion due to chemical attack from solutes found in groundwater and leached from the rock they are in contact with. To provide an understanding of areas where the potential for corrosion is greatest, then the relevant data need to be brought together and an assessment undertaken of the potential for corrosion. By combining hydrogeologcial and geochemical data then the likelihood of corrosion occurring to the underground asset can be quantified and maps produced to inform operators of these assets to be informed.

B.2.9.3 Detailed description

Use case description	
Name	Providing data to assess Corrosivity to Underground Assets
Priority	Medium
Description	The user selects the relevant geographic area and searches for hydrogeological and geochemical data: depth to water table, geochemical information - sulphate/sulphides, pH, moisture content, organic carbon and resistivity.

Pre-condition	Hydrogeological and geochemical data are available in line with INSPIRE specifications. A specific vocabulary related to the user requirements is available with a “mapping” between hydrogeological terms and user’s terms.
Flow of events – Basic path	
Step 1	The user selects on a geo-portal the area of interest and searches in a metadata catalogue for geological maps and other relevant hydrogeological and geochemical data.
Step 2	The user displays the hydrogeological map and accesses detailed information about the groundwater system (depth to water table and moisture content), rock properties (resistivity) and geochemistry (pH, Organic Carbon and sulphate/sulphide concentration)
Step 3	The user accesses the relevant data to get the values of the properties and combines them to produce potential corrosion maps for each type of asset.
Step 4	The user uploads the gridded data back into a portal to provide information for the operator of the asset.
Flow of events – Alternative path	
Post-conditions	
Post-condition	The user has a set of hydrogeological and geochemical data related to the selected area as well as a map of potential corrosivity..
Data source: *INSPIRE-conformant Geology data set provided by Member Sate*	
Description	Hydrogeological and geochemical data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	Scale relevant to the application (tbd)
Delivery	INSPIRE Geology GML Application schema
Documentation	INSPIRE Geology Data Specification

B.2.9.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

Hydrogeological units with:
- their related polygons
- water table depth
- rock lithology

Unsaturated zone data:
- moisture content

Geochemical data:
- pH
- Sulphate/sulphide concentration

Geophysical data:
- Resistivity of the rocks

B.2.9.5 Relationship with other INSPIRE Themes

This use case has some relationships with the following INSPIRE data themes:

- Soils: moisture content:
- Geology: the geologic property of an aquifer

To understand corrosivity, it is important to quantify groundwater flow and solute transport, therefore data for groundwater quantity and quality need to be available.

The majority of groundwater measurements are undertaken at a well, therefore the WaterWell feature type needs to be included.

B.2.10 UC10: Providing data to plan tunneling operations safely and effectively

This use case is related to example of use:

- AQ-07: Groundwater as a hazard

B.2.10.1 Overview and involved actors

The goal of this use case is therefore to deliver hydrogeological data to professionals responsible for tunneling operations.

Actors:

- Geological surveys to provide geological information (Geological Surveys represent the Member States)
- Other organizations to provide relevant hydrogoelogical data, e.g. groundwater level.
- Professionals responsible for planning and undertaking tunneling operations.

B.2.10.2 Narrative description

Tunneling is an activity that required suitable knowledge of the geological and hydrogeological conditions to be undertaken safely and cost effectively. Knowledge of the ground conditions that are likely to be encountered is very important to ensure that the correct tunnel boring techniques are used and that the operations are conducted in a safe a way as possible. Understanding of the saturation of the deposits being tunnelled through is equally important to ensure the safe undertaking of underground working. Therefore, building a 3D understanding of the geology combined with the variation of groundwater heads is important in planning any tunneling operation.

B.2.10.3 Detailed description

Use case description	
Name	Providing data to plan tunneling operations safely and effectively
Priority	Medium
Description	The user selects the relevant geographic area and searches for geological and hydrogeological data. The geological data will be used to construct a 3D model
Pre-condition	Geological and hydrogeological data are available in line with INSPIRE specifications. A specific vocabulary related to the user requirements is available with a “mapping” between hydrogeological terms and user’s terms.
Flow of events – Basic path	
Step 1	The user selects on a geo-portal the area of interest and searches in a metadata catalogue for geological maps and other relevant hydrogeological data.
Step 2	The user accesses a DTM, borehole data and other relevant data to produce a 3D geological model.
Step 3	The user displays the hydrogeological map and accesses detailed information about the groundwater system (water table and moisture content).
Step 4	The user accesses the relevant data to get the values of the properties and combines them with the 3D geolgocial model to produce the required understanding of rock properties and moisture content to plan the tunneling activities.
Step 5	The user uploads the 3D geological model with groundwater data back into a portal to provide information for the tunneling organisation.
Flow of events – Alternative path	

Post-conditions	
Post-condition	The user has a 3D geological model and a set of hydrogeological data related to the selected area. The can be combined to produce a 4D understanding of groundwater flow.
Data source: *INSPIRE-conformant Geology data set provided by Member Sate*	
Description	Hydrogeological and geochemical data from national sources.
Data provider	Each Member State
Geographic scope	All EU Member States, with appropriate cross border cooperation where necessary
Thematic scope	Geology
Scale, resolution	Scale relevant to the application (tbd)
Delivery	INSPIRE Geology GML Application schema
Documentation	INSPIRE Geology Data Specification

B.2.10.4 Requirements from the use case

Analyzing the use case, there is a need to provide the following objects and attributes:

Topographic data:
- DTM

Geological data:
- Borehole logs
- 2D maps
- Previously created cross sections

Hydrogeological units with:
- their related polygons
- water table depth
- rock lithology

Unsaturated zone data:
- moisture content

B.2.10.5 Relationship with other INSPIRE Themes

This use case has some relationships with the following INSPIRE data themes:
- Soils: moisture content:
- Elevation: DTM
- Geology: the geologic property of an aquifer

To understand water movement around any underground structure, it is important to quantify groundwater flow, therefore data for groundwater quantity need to be available.

The majority of groundwater measurements are undertaken at a well, therefore the WaterWell feature type needs to be included.

Annex C
(informative)

Aquifers and Groundwater bodies

INTRODUCTION

Water has always been the basis for human existence. World water use in the past century grew twice as fast as world population. Groundwater has been described as “our Hidden Asset” and although this is a truism groundwater makes up about twenty percent of the world's fresh water supply. As far as “clean”, drinking water resources are concerned it is even much more. Groundwater is one of the most important component of water cycle in environment (Fig. 1).

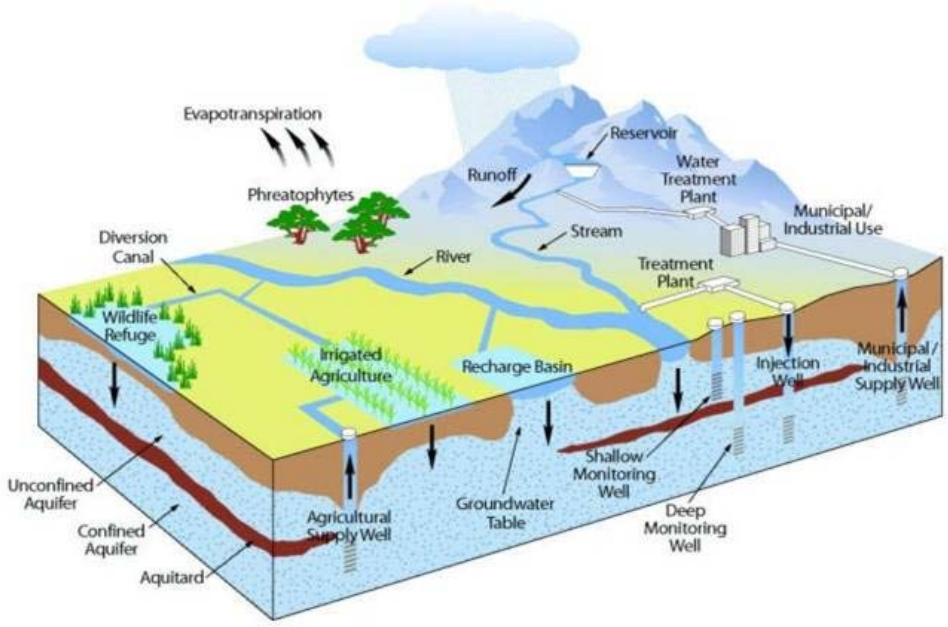


Fig. 1

The European Union recognized the need for a consistent framework for the legislation on water management. According to the Water Framework Directive (WFD) introduced in 2000 water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.

Hydrogeology describe the flow, condition of occurrence and behavior of water in underground environment. It is a science located between hydrology and geology, while both have a strong influence on the groundwater resources creation. Hydrological processes are responsible e. g. for quantity of water supply by the recharge area to aquifers. On the other hand the physical properties and composition of the geologic materials (rocks and sediments) create the main environment for groundwater flow and storage, rocks and sediments also influent on groundwater quality in terms of their chemical composition.

More accurately, groundwater is both a resource and a problem depending on what activity is being undertaken. A positive benefit is abstraction for drinking water supply whereas groundwater flooding causes significant problems to properties and transport infrastructure. Unlike geology hydrogeology has a direct influence on environment, groundwater abstraction not only provides water for human but also cause changes in water flow and in some cases may have a dramatic impact on water relations.

Overexploitation in the area where the groundwater dependent ecosystems are located may change water table level or the chemical composition of water and in effect consequently lead to irreversible changes in environment.
In terms of INSPIRE groundwater domain has many connections and dependency on other human activities described in other themes (Area Management, Soil, Environmental Facilities, Energy Resources, Hydrography, Protected Sites, Utility and Governmental Services). Contamination introduce to surface water system takes years to be clean out. In case of groundwater when it is difficult to predict of contamination movement and its behaviour in complicated system of rock it needs a lot of efforts to clean the environment and take much more time.
This document intends to introduce groundwater issues for the purposes of the members of the INSPIRE Geology and Mineral Resources TWG.

BACKGROUND TO GROUNDWATER PROCESSES

One suitable source of background for groundwater issues is the UK's groundwater forum website – *www.groundwateruk.org*. The section "Groundwater in Depth", see *www.groundwateruk.org/Groundwater-in-depth.aspx*, has some excellent articles on some of the issues introduced below.

[text to be written – AGH and refer to suitable figures] - for DS 2.0

DESCRIPTION OF ISSUES

Traditionally the study of groundwater has been categorised as examining either quality and quantity. The former examining the amount of groundwater flow and the latter examining the solutes dissolved in groundwater. However, the occurrence and use groundwater is much wider than this. For example as part of climate change mitigation then groundwater systems have been recognised as heat stores for ground source heat pumps and saline aquifers for the disposal of supercritical CO2.

Groundwater flow

Groundwater flow is important for supporting abstractions for water supply for domestic (i.e. people in their homes) as well as industrial purposes. It is also important to support river flows for ecological purposes, amenity value (people to enjoy their surroundings), etc. Groundwater dependent ecosystems, as the name suggests, are also supported by sub-surface flows. These include wetlands, which can be small areas fed by seeps to large nationally significant bodies.

Pollution

Aquifers are vulnerable to polluting activities. These include "catastrophic" events such as accidental spills, i.e. a road tanker crash to diffuse pollution from agricultural activities. European countries have a long history of industrial activities and groundwater has been polluted from these processes. Understanding of the vulnerability of groundwater systems to pollution from current activities and clean-up of aquifers from past activities is equally important. Polluted groundwater can contribute to pollution in rivers, lakes and the seas as well as causing hazards for activities such as mining, etc.

Natural attenuation

Reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The 'natural attenuation processes' that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favourable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants.

Saline aquifers

Saline aquifers occur in a range of settings. Aquifers in close proximity to estuaries and the sea are often saline. Deep aquifers with old or "connate" waters are also highly saline. Basins of internal drainage, where evaporation is the only outflow are highly saline. Saline intrusion is a problem where abstraction occurs in aquifers close to saline water bodies. Careful management has to be undertaken to avoid despoiling the systems permanently. However, deep saline aquifers are being considered for disposal of supercritical CO_2. Finally highly saline aquifers that are the result of evaporative processes often contain economically important minerals and are exploited commercially.

Geotechnical considerations

The interaction of groundwater with the built environment is extremely important. As the water content of the ground changes so does its geotechnical properties. For example, rising groundwater in cities causes problems with deep foundations and tunnels. An understanding of water movement in the sub-surface is, therefore, important to ensure safe construction of buildings. Dewatering of aquifers for temporary works is also important to allow sub-water table working in construction works.

Groundwater monitoring

Groundwater, in view of the prevalence and quality are very important source of supply for the population with drinking water. Because of their economic importance and the widespread risks to the quality of pollution discharged to the ground, they must be special protection. This protection is achieved, inter alia, using the network of monitoring the status of both qualitative and quantitative groundwater.

Geohazards

As well as being a resource, groundwater can cause problems either by appearing at the surface or by entering sub-surface structures. Groundwater flooding is one such problem. Under extreme recharge events, the water table can rise to the surface and result in flooding. Groundwater flooding differs from surface water flooding in that it is often long-lasting, typically of the order of weeks to months and can affect areas not identified in traditional flood risk mapping. Unlike surface water floods, it is not possible to control this phenomena easily by flood defences.

Other geohazards that are related to groundwater include:
- landslides
- swell-shrink clays
- subsidence

All of these geohazards need an assessment of water movement in the sub-surface to understand how they occur and what influence human activity and climate change will have on them.

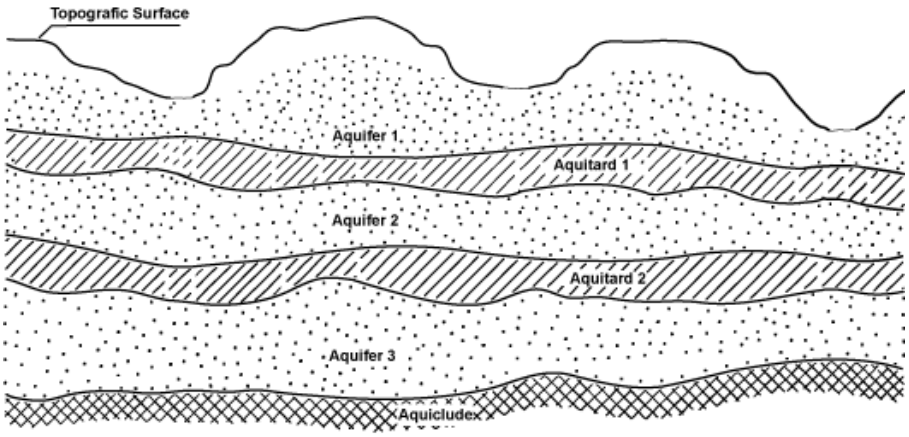
Heat

Heat flows both into and out of aquifers are increasingly being recognised as a way of reducing reliance on fossil fuels. Groundwater systems and aquifers are being developed to be used as a temporary store for heat. Systems based on pumping groundwater into and out of aquifer using boreholes such as Ground Source Heat Pumps (GSHP) or heat exchange in trenches or boreholes for Ground Coupled Heat Pumps (GCHP). Groundwater can also be used to exploit hotter rocks close to the surface by pumping cold water down or abstracting hot water. All these systems can be used to heat, cool and power systems in buildings.

Mineral resources

Exploitation of mineral resources requires the control of water where it isn't wanted and supply of water where it is in short supply. So-called "wet working" of mines requires removal of water where it enters the mine. However mining requires water to operate its processes so in some areas, where water is scare, then groundwater can be used for supply purposes. Groundwater can be rich in minerals and the economic extraction of minerals from groundwaters is possible for high value mineral such as Lithium. As well as this mineral waters can be thought of groundwater as an economic resource, with the dissolved solids giving the water its taste.

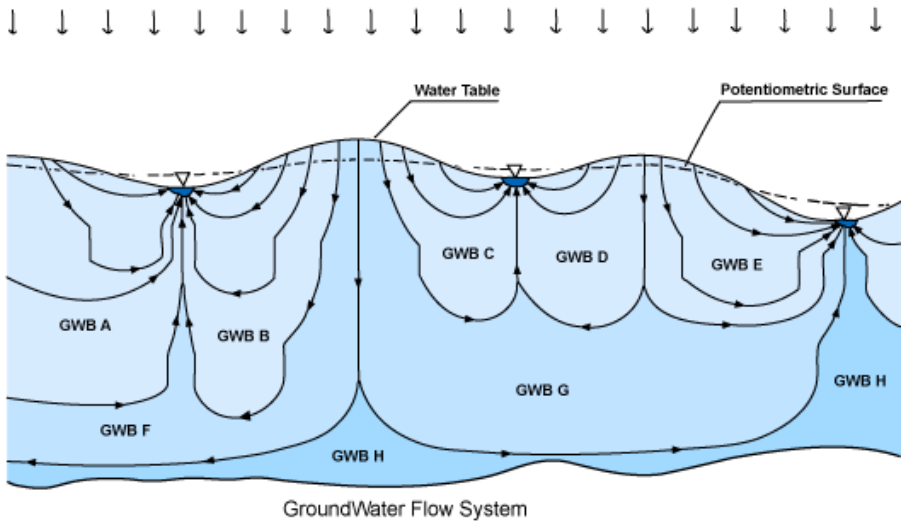
APPROACH TO DATA MODELS



Aquifer System

Fig. 2 Aquifer System

The Aquifer System is dependent of rock properties and its permeability for water flow. Generally two main components are Aquifers (e.g. sand and gravel) where the water flow is accessible and Aquitard which are poorly permeable formation (e.g. clay) that does not yield water freely to a well or a spring. However, an aquitard may transmit appreciable water to or from adjacent aquifers.

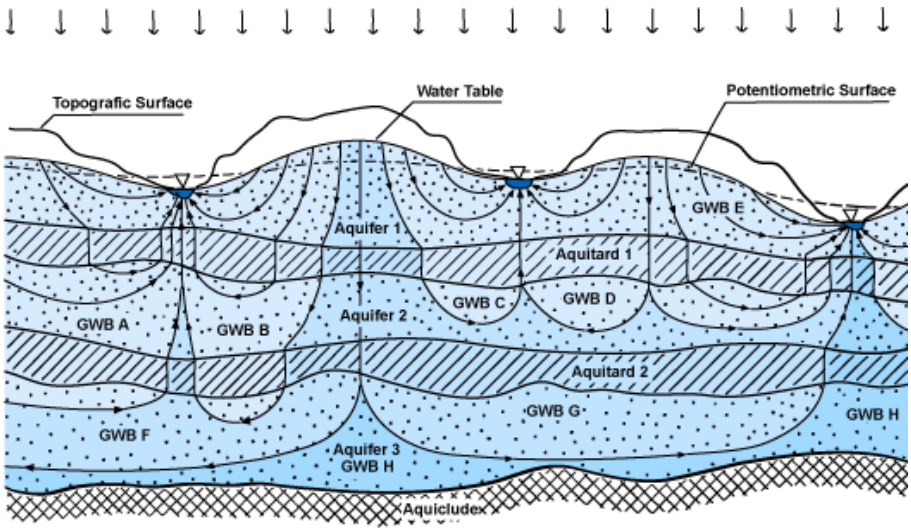


GroundWater Flow System

Fig. 3 Groundwater Flow System

However, the processes affecting groundwater flow are much more complicated and depend not only on rocks building the geological structures. The Groundwater Flow System is a set of Groundwater Bodies (GWB) which are delineated on the hydrodynamic condition. GWBs can cross traditional aquifer system (fig. 3) and depend on the amount water incorporated into the system as well as on the abstraction features (rivers, lakes, wells, intakes).

The basic idea of INSPIRE model for groundwater is to identify two basic elements: Aquifer System (dependent on the geological condition) and Groundwater Flow System. Both components create Hydrogeological System.



Hydrogeological System = Aquifer System + GroundWater Flow System

Fig. 4 Hydrogeological System

The mutual relationships between those components create and build the condition for groundwater flow. The main assessment of model is base on the hydrodynamic processes (groundwater flow).

RELEVANT EU LEGISLATION

[Introduction required – AGH/TN]

- Bathing Water Directive 76/160/EEC
- Birds Directive 79/409/EEC
- Drinking Water Directive 98/83/EEC
- Major Accidents (Seveso) Directive 96/82/EC
- Environment Impact Assessment 85/337/EEC
- Sewage Sludge Directive 86/278/EEC
- Urban Wastewater Treatment Directive 91/271/EEC
- Plant Protection Products Directive 91/414/EEC
- Nitrates Directive 91/676/EEC
- Habitats Directive 92/43/EEC
- Integrated Pollution Prevention Control 96/61/EEC
- Nitrates Directive
- Urban Wastewater Treatment Directive
- Plant Protection Products Directive - Directive 91/414/EEC, OJ L230 of 19.08.1991
- Biocides Directive - Directive 98/8/EC, OJ L123 of 24.04.1998
- Integrated Pollution Prevention and Control (IPPC) Directive - Directive 96/61/EEC, OJ L257 of 10.10.1996
- Landfill Directive - Directive 99/31/EC, OJ L182 of 16.07.1999
- Waste Framework Directive - Directive 2006/12/EC, OJ L102 of 11.04.2006
- Construction Product Directive - Directive 89/106/EC, OJ L40 of 11.02.1989
- Floods Directive 2007/60/EC
- Water Framework Directive (2000/60/EC)
- Groundwater Directive (2006/118/EC)
- Groundwater Directive (80/ 68/EEC)

Annex D
(informative)

Rock type and lithology

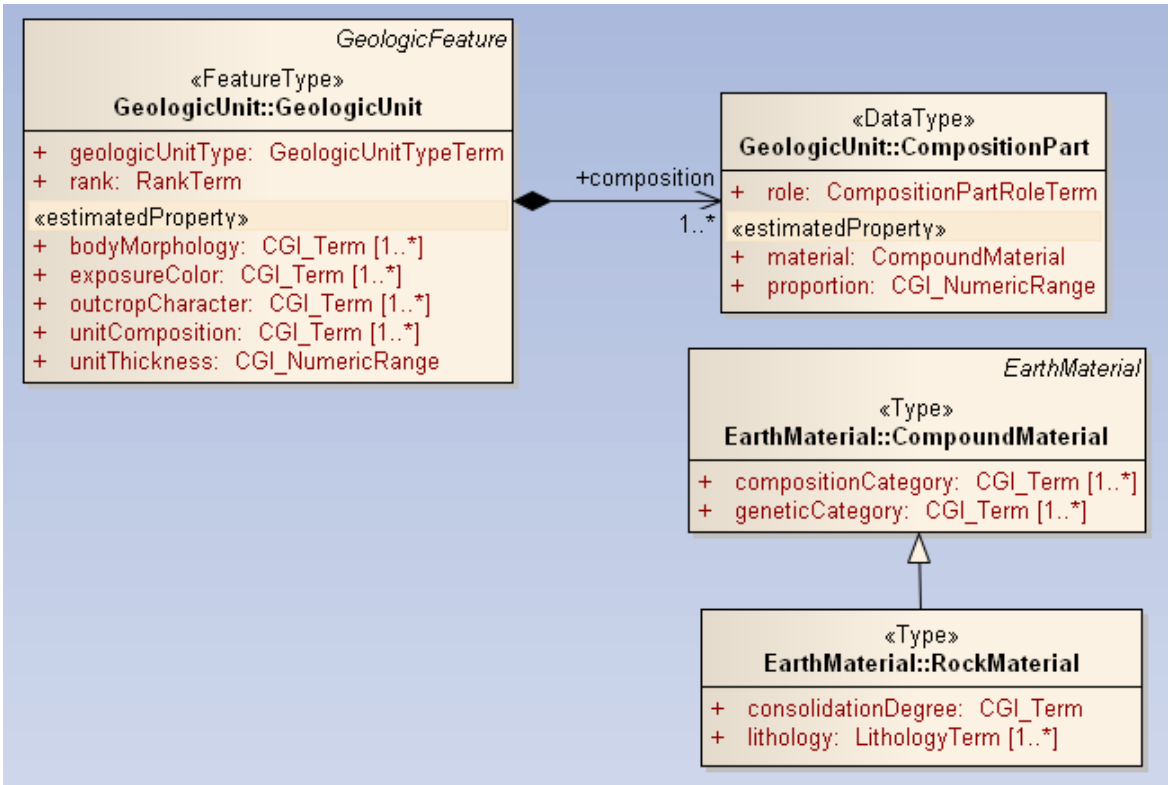
Specific issue about the rock type

A geologic unit represents a body of material in the Earth; this earth material is composed of several types of rocks, or minerals, with various proportions, and ideally defined according to physical and chemical properties but genesis information is also taken into account. The rock material, whose name is indicated in the property "lithology", could have been transformed partially or totally by alteration or other processes. As a result lithology code list contains a lot of values to describe these natural objects (several hundreds).
To present geologic units in a way easier to understand it is possible to classify them according to a more simple classification (using the controlled concept modeling pattern) describing the main rock types.

The Geology data model offers these two options:

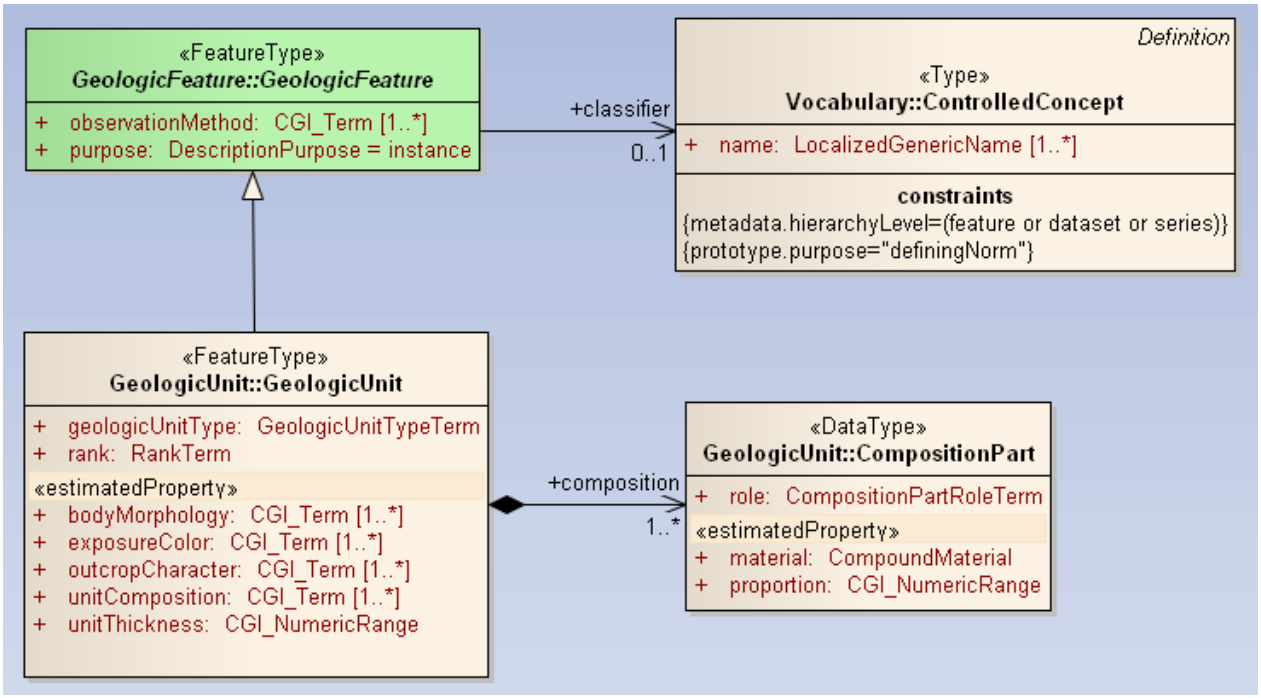
- (1): A detailed description of earth material to meet the requirements of the use cases (the need to know various properties of rocks)
- (2): A simple classification of geologic units according to the type of rocks

Option (1): the composition of a geologic unit is described by EarthMaterial classes (CompoundMaterial and one of its sub-type RockMaterial, the property is lithology (the geological term used to described the rock or material of a unit).



The code list for lithology is very detailed, representing the variety of rocks in the nature. The OneGeology-Europe project provides a list of about 200 terms to describe the rock types in Europe at a scale of about 1:1Million. To describe rocks at a scale of about 1:50 K (which is often the scale required to address geological issues defined in the use cases), the number of items will increase up to several hundreds.
The terms used by geologists are also useful for users of geological data, but are not understandable by citizens. A proposal is then to group scientific terms into a few classes of more wellknown terms: **this is option (2)**.

A possibility offered by the GeoSciML data model is to use the "Classifier" of geologic features (see diagram below) whose definition is "to point to a standard description or definition of the feature type (eg; the definition of a particular Geologic Unit in a stratigraphic lexicon)".



This is an example for classifying rock units, for example against applied geology classes. Several ranges of classification vocabularies could be defined, and a process (run by geologist) will make the classification of geologic units according to lithology but also other properties (physical and chemical properties, influence of alteration, and structures, …).

Issue: This option to use classifier for lithology could be a problem as lithology is a property, not a classification. This property is defined in the RockMaterial so it could happen inconsistency between the two points of view. A proposal to solve this particular case is to provide a high level lithology for the lithology property.

Table of simplified terms to "classify" geologic units
This table shows the links with the main terms defined in the OneGeology-Europe project.

	Suggested simplified term	Grouping of OneGeologyEurope Lithology
1	Clay	Mud
2	Sand	Sand, Gravel
3	Peat, marl	Carbonate sediment ,Biogenic sediment
4	Till	Diamicton
5	Claystone	Mudstone, Generic mudstone
6	Sandstone	Sandstone, Conglomerate, Diamictite
7	limestone, chalk	Carbonate sedimentary rock
8	Gypsum, anhydrite	Evaporite
9	Coal	Coal

10	Other sedimentary rock	Non-clastic siliceous sedimentary rock, Iron rich sedimentary rock
11	Granitic rock	Granitoid, Pegmatite, Aplite, Syenitoid
12	Gabbroic rock	Dioritoid, Gabbroid, Anorthositic rock, Doleritic rock
13	Other plutonic rock	Foid dioritoid, Foid gabbroid, Foid syenitoid, Foidolite
14	Basaltic rock	Basalt, Andesite
15	Rhyolitic rock	Rhyolitoid, Dacite, Trachytoid
16	Other volcanic rock	Phonolitoid, Tephritoid, Foiditoid
17	Porphyry	Porphyry
18	Ultramafic igneous rock	Ultramafic igneous rock
19	Other igneous rock	Exotic composition igneous rock
20	Material formed by weathering	Material formed in surficial environment
21	Volcanic blocks, ash	Fragmental igneous material
22	Gneiss	Gneiss
23	Schist, slate	Phyllite,Slate, Schist, Chlorite, actinolite epidote metamorphic rock
24	Marble	Marble
25	Other metamorphic rock	Serpentinite, Quartzite, Amphibolite, Granulite, Eclogite, migmatite, Granofels, Metasomatic rock
26	Rocks in crush zones	Fault-related material and Impact generated material
27	Tuffite	Tuffite
27	Breccia	Breccia

Annex E
(informative)

Code lists for geology, geophysics and hydrogeology

3DMeasurementTypeValue
Code list

Term	Definition
3DSeismics	

AlterationTypeTerm
Code list
(CGI_Term, Class: AlterationDescription, Attribute: alterationType)

Term	Definition
advanced argillic alteration	
albitic alteration	
alteration type not specified	Rock is altered, but type not specified. Any alteration type allowed.
alunitic alteration	
argillic alteration	
calcsilicate alteration	
carbonate alteration	
chloritic alteration	
deuteric alteration	
epidote alteration	
greisen	
hematitic alteration	
kaolinitic alteration	
not altered	Rock or sediment not altered.
potassic alteration	
propylitic alteration	
pyritic alteration	
red rock alteration	
saussuritised	
sericitic alteration	
serpentinisation	
silicification	
unknown alteration	
uralitisation	
zeolitic alteration	

AnthropogenicGeomorphologicFeatureTypeTerm
Code list

Term	Definition
Anthropogenic feature	An artificial feature on the earth's surface (including those in shallow water), having a characteristic shape and range in composition, composed of unconsolidated earthy, organic materials, artificial materials, or rock, that is the direct result of human manipulation or activities; can be either constructional (e.g., artificial levee) or destructional (quarry).
Artificial collapsed depression	A collapse basin, commonly a closed depression, which is the direct result of surficial subsidence associated with subsurface mining (e.g., long-wall mining).
Artificial drainage pattern	Human-made networks of drainage structures (ditches, canals, etc.) built primarily to lower or control the local water table in low lying, flat topography such as glacial lakebeds, broad flood plains, low coastal plains, or marshes most commonly in humid climates. (Irrigation ditches found in arid and semiarid climates, which bring water into the fields, should not be confused with drainage structures).
Artificial Ground	Geologic unit defined by genesis involving direct human action to deposit or modify material.
Artificial levee	An artificial embankment constructed along the bank of a watercourse or an arm of the sea, to protect land from inundation or to confine streamflow to its channel. Dike along the side of a river channel erected to prevent overflow during floods, ordinarily running more or less along the channel direction and near the natural levee crests of alluvialting streams. Term is also used for structures designed to prevent fooding by seas, lakes, etc.
Bell pit	In mining, a bell-shaped excavation in which the extracted material was dragged to a central shaft; an obsolete method for extracting mineral deposits from shallow depths. Disused bell pits are usually collapsed and/or partly backfilled with rock waste.
Beveled cut	A bank or slope portion of a cut excavated into unconsolidated material (regolith) or bedrock as in a roadcut, whose slope gradient has been mechanically reduced to a subdued angle (e.g. to < 33 %) to increase slope stability, reduce erosion, or to facilitate revegetation.
Borrow pit	An excavated area from which earthy material has been removed typically for construction purposes offsite; also called barrow pit.
Burial mound	A small human-made hill, composed of debris accumulated during successive occupations of the site, or of earth heaped up to mark a burial site; also called mound.
Conservation terrace	An earthen embankment constructed across a slope for conducting water from above at a regulated flow to prevent accelerated erosion and to conserve water.
Cut	A passage, incision, or space from which material has been excavated, such as a road cut or a railroad cut.
Cutbank	a) A slope or wall portion of a cut excavated into unconsolidated material (regolith) or bedrock, as in a borrow pit. It may stand nearly vertical resulting from collapse as the base is undercut during excavation or by erosion, or it may be reduced by subsequent erosion to a more subdued angle by slope wash. b) (not preferred – refer to escarpment, meander scar, bluff) [colloquial – western USA] – A steep, bare slope formed by lateral migration of a stream.
Ditch	An open and usually unpaved (unlined), channel or trench excavated to convey water for drainage (removal) or irrigation (addition) to or from a landscape; smaller than a canal; some ditches are modified natural waterways.
Double-bedding mound	Raised, linear mounds with subdued, convex slope cross-sections constructed by mounding and shaping spoil material dredged from adjacent drainage ditches and placed over natural soil. The mounds serve as preferred, better-drained bedding areas for managed timber plantations; common in the lower coastal plains of the Atlantic and Gulf coasts, USA.
Dredge spoil bank	A subaerial mound or ridge that permanently stands above the water composed of dredge spoils; randomly mixed sediments deposited during dredging and dumping.
Dredged channel	A roughly linear, deep water area formed by a dredging operation for navigation purposes
Dredge-deposit shoal	A subaqueous area, substantially shallower than the surrounding area that resulted from the deposition of materials from dredging and dumping

Term	Definition
Dump	An area of smooth or uneven accumulations or piles of waste rock, earthy material, or general refuse that without major reclamation are incapable of supporting plants.
Excavation Unit	Geologic unit defined by human-made genesis involving excavation. Not necessarily defined by landform (a hole...), as they could have been subsequently filled/landscaped etc. If the excavation is filled becomes an excavation with artificial ground wholly or partly superimposed on it. This sort of thing can become quite important in urban geology where an excavation can be filled and landscaped.
Fill	(a) Human-constructed deposits of natural earth materials (e.g., soil, gravel, rock) and waste materials (e.g., tailings or spoil from dredging) used to fill a depression, to extend shore land into a body of water, or in building dams. (b) Soil or loose rock used to raise the surface level of low-lying land, such as an embankment to fill a hollow or ravine in roads construction.
Filled marshland	A subaerial soil area composed of fill materials (construction debris, dredged or pumped sandy or shell-rich sediments, etc.) deposited and smoothed to provide building sites and associated uses (e.g. lawns, driveways, parking lots). These fill materials are typically 0.5 to 3 m thick and have been deposited unconformably over natural soils.
Gravel pit	A depression, ditch or pit excavated to furnish gravel for roads or other construction purposes; a type of borrow pit.
Hillslope terrace	A raised, generally horizontal strip of earth and/or rock bounded by a down-slope berm or retaining wall, constructed along a contour on a hillslope to make land suitable for tillage and to prevent accelerated erosion; common in steep terrain, both archaic (e.g. Peru) and modern (e.g. Nepal).
Impact crater (anthropogenic)	A generally circular or elliptical depression formed by hypervelocity impact of an experimental projectile or ordinance into earthy or rock material.
Infilled ground	Areas where the ground has been cut (formerly termed away (excavated) and then had deposited: partly or wholly back-filled workings such as pits, quarries, opencast sites; landfill sites (except sites where material is dumped or spread over the natural ground surface; see landraise).
Landfill site	Waste disposal site used for the controlled deposit of the waste onto or into land.
Landraise site	A specific type of landfill site where the waste is deposited on the pre-existing natural ground surface; the deposit is classified as made ground in the BGS Rock Classification Scheme.
Landscaped ground	Areas where the original surface has ground been extensively remodelled, but where it is impractical or impossible to separately delineate areas of worked (excavated) ground and made ground.
Leveled land	A land area, usually a field, that has been mechanically flattened or smoothed to facilitate management practices such as flood irrigation; as a result the natural soil has been partially or completely modified (e.g., truncated or buried).
Log landing	A comparatively level area, usually with road access, constructed or cut into steeper slopes and used for sorting logs during timber harvest operations.
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 defences; spoil (waste) heaps; coastal reclamation fill; offshore dumping grounds; constructional
fill (landraise).	
Middden	A mound or stratum of refuse (broken pots, ashes, food remains, etc.) normally found on the site of an ancient settlement.
Mound (anthropogenic)	A small, human-made hill, composed either of debris accumulated during successive occupations of the site (e.g. tell) or of earth heaped up to mark a burial site (e.g. burial mound).
Openpit mine	A relatively large depression resulting from the excavation of material and redistribution of overburden associated with surficial mining operations.
Pit	A depression, ditch or pit excavated to furnish gravel for roads or other construction purposes; a type of borrow pit.
Pond (anthropogenic)	(a) A body of standing fresh water occupying a small surface artificial depression,

Term	Definition
	usually smaller than a lake and larger than a pool. (b) A small artificial body of water, used as a source of water.
Pool (anthropogenic)	A small body of standing water, usually fresh; e.g. a stagnant body of water in an abandoned pit, or a transient puddle in an artificial depression following a rain.
Quarry	Excavation areas, open to the sky, usually for the extraction of stone.
Railroad bed	The trace or track of a railroad route, commonly constructed slightly above the adjacent land, and composed mostly of earthy materials (gravel, rock fragments, etc.). Abandoned or reclaimed beds may no longer be topographically or visually distinct, but the materials used to construct them may still be a significant portion of the soil zone.
Railroad cut	A common anthropogenic feature, typically a microfeature, consisting of the sloping, cut surface flanking a railroad bed on one or both sides, that remains after local topography is minimized by cutting an elongated depression through higher ground during railroad construction; a type of cutbank.
Reclaimed land	a) A land area composed of earthy fill material that has been placed and shaped to approximate natural contours, commonly part of land-reclamation efforts after mining operations; b) A land area, commonly submerged in its native state, that has been protected by artificial structures (e.g. dikes) and drained for agricultural or other purposes (e.g. polder).
Reservoir lake	An inland body of permanently standing water, usually fresh, occupying a depression on the Earth's surface closed by a dam, generally of appreciable size (larger than a pond) and too deep to permit vegetation (excluding subaqueous vegetation) to take root completely across the expanse of water.
Road bed	The trace or track of a wheeled vehicle route that may or may not be raised slightly above the adjacent land, and composed of earthy fill material (gravel, rock fragments, etc.) or local soil material. Traffic can alter various soil properties primarily by compaction. Abandoned or reclaimed beds may no longer be topographically or visually distinct. However, materials used to construct beds or changes in soil properties may continue to have a significant impact on soil management or plant growth.
Road cut	A common anthropogenic feature, typically a microfeature, consisting of the sloping, cut surface flanking a road bed on one or both sides, that remains after local topography is minimized by cutting an elongated depression through higher ground during road construction; a type of cutbank.
Sand pit	A depression, ditch or pit excavated to furnish sand for roads or other construction purposes offsite; a type of borrow pit.
Sanitary landfill	A land area where municipal solid waste is buried in a manner engineered to minimize environmental degradation. Commonly the waste is compacted and ultimately covered with soil or other earthy material.
Scalped area	a) A modified slope, feature, or land area where much or all of the natural soil has been mechanically removed (e.g. scraped off) due to construction or other management practices. b) A forest soil area where the ground vegetation and root mat has been removed to expose mineral soil in preparation for planting or seeding.
Sewage lagoon	Any artificial pond or other water-filled excavation for the natural oxidation of sewage or disposal of animal manure.
Skid trail	Irregularly spaced, roughly linear to radial depressions or small mounds associated with shallow to deep soil disturbance caused by dragging logs across a slope from where they were cut down to a central processing area such as a log landing during timber harvest operations.
Spoil bank	A bank, mound, or other artificial accumulation of rock debris and earthy dump deposits removed from ditches, strip mines, or other excavations.
Spoil pile	(a) A bank, mound, or other artificial accumulation composed of spoil; e.g., an embankment of earthy material removed from a ditch and deposited alongside it. (b) A pile of refuse material from an excavation or mining operation; e.g., a pile of dirt removed from, and stacked at the surface of a mine in a conical heap or in layers.
Subsidence area	An area subject to a process of subsidence induced by antropogenic activities, for

Term	Definition
(antrhopogenic)	example gas or groundwater production
Surface mine	A depression, open to the sky, resulting from the surface extraction of earthy material (e.g. soil / fill) or bedrock material (e.g. coal).
Worked ground	Areas where the ground is known to have been cut away (excavated) by man: quarries, pits, rail and road cuttings, cut away landscaping, dredged channels.

BoreholeDrillingMethodCode

Code list

Term	Definition
air core	http://en.wikipedia.org/wiki/Drilling_rig#Air_core_drilling
auger	http://en.wikipedia.org/wiki/Drilling_rig#Auger_drilling
cable tool	http://en.wikipedia.org/wiki/Drilling_rig#Cable_tool_drilling
diamond core	http://en.wikipedia.org/wiki/Drilling_rig#Diamond_core_drilling
direct push	http://en.wikipedia.org/wiki/Drilling_rig#Direct_Push_Rigs
hand auger	
hydraulic rotary	http://en.wikipedia.org/wiki/Drilling_rig#Hydraulic-rotary_drilling
RAB	http://en.wikipedia.org/wiki/Drilling_rig#Percussion_rotary_air_blast_drilling
RC	http://en.wikipedia.org/wiki/Drilling_rig#Reverse_circulation
unknown	
vibratory	http://en.wikipedia.org/wiki/Drilling_rig#Sonic_%28Vibratory%29_Drilling

BoreholeInclinationCode

Code list

Term	Definition
horizontal	
inclined down	
inclined up	
vertical	

BoreholepurposeCode

Code list

Term	Definition
Aquaculture	To supply water to aquaculture, for example fish farming
Contingency water supply	Stand-by water supply in case of water deficiency.
Dewatering	dewatering is the removal of water from solid material or soil by wet classification, centrifugation, filtration, or similar solid-liquid separation processes. Removing or draining water from a riverbed, construction site, caisson, or mine shaft, by pumping or evaporation. This is often done during the site development phase of a major construction project due to a high water table. Usually involves the use of "dewatering" pumps. Methods of dewatering include Wellpoint, Deep Well and Eductor systems. http://en.wikipedia.org/wiki/Dewatering
Disposal	A well, often a depleted oil or gas well, into which waste fluids can be injected for safe disposal. Disposal wells typically are subject to regulatory requirements to avoid the contamination of freshwater aquifers. http://www.glossary.oilfield.slb.com/Display.cfm?Term=disposal%20well
Drinking water supply	Well construction for drinking water
Emergency water supply	Well construction for emergency water supply (e.g. extinguish a fire)

Term	Definition
Environmental monitoring	Groundwater chemistry and groundwater level is monitored.
exploration and exploitation of nonmetallic mineral deposits	Prospecting with regard to the availability of nonmetallic mineral deposits such as building stones, lime stone, gravel, sand, clay, kaolin, diatomite etc. (mainly for construction purposes, cement and ceramic or glass industry) and planning to be excavated
exploration and exploitation of raw material	Examination of the subsurface with regard to the availability of earth-borne raw materials in general and planning the extraction thereof. Exploration: the discovery and identification of mineral resources, in the assessment of their importance and in the evaluation of the economic benefit of the eventual exploitation of the potentially economic deposit. Exploitation: All works and activities done to extract mineral resources with a view to mining and marketing them
exploration of natural underground storage space	Examination of the subsurface's ability to store various materials such as natural gas, captured carbon, etc.
exploration on exploitation of energy resources	Examination of the subsurface with regard to the availability of fossil energy resources (e.g. oil, gas, coal, lignite) and planning the extraction thereof
FlowingShot	A flowing shot hole is a drilled (seismic) hole that has entered an underground water source that has sufficient pressure to cause the hole to "overflow". http://www.etsurvey.com/water/h20main.htm
geochemical survey, analyses	Examination of chemical properties of the rock formation and /or the porosity fluids (samples to be analyzed)
geological survey	General examination of an area's geological entities
geophysical survey	Examination of the subsurface's geophysical properties such as electric resistivity, seismicity, gravity, radiation, etc.
geotechnical survey, construction site characterization	Examination of the subsurface's properties with respect to slope stability, construction of building foundations, tunnels, etc.;Geotechnical investigations performed to obtain information on the physical properties of soil and rock around a site to design earthworks and foundations for proposed structures and for repair of distress to earthworks and structures caused by subsurface conditions. GEUS: Geotechnical drill holes made to investigate the ground before construction work.- Geotechnical : A geotechnical well is defined as a hole drilled for the exclusive purpose of collecting geotechnical data, including soil samples, vapour samples, and water samples obtained through bailing, driven sampler or other similar methods. http://www.adwr.state.az.us/dwr/Content/Find_by_Category/Laws_and_Rules/files /SPS/Well%20Construction/Well%20Construction%20and%20LIcensing%20-%20WL7.pdf
geothermal energy, geothermal heat exchangers	Exploration pertaining to the utiliztation of geothermal energy resources and design of geothermal heat pumps. Geothermal energy is the form of energy stored below the surface of the solid earth as heat. Borehole heat exchangers are heat exchangers which are installed vertically or oblique in the underground.
Groundwater level monitoring	Construction of a gauge for recording grondwater level changes
hydrogeological survey, water management	Examination of groundwater flow (i.e. the hydraulic characteristics of an aquifer), the chemical properties of ground water, and transport of particles, solutes, and energy, as well as the management of the sustainable use of ground water resources
Industrial water supply	Well construction for industrial water supply
Irrigation	Well construction for irrigation purposes
Mineral	A non-E&amp P well drilled for the purpose of locating and/or extracting a mineral from the subsurface, usually through the injection and/or extraction of mineral-bearing fluids. http://posc.org/technical/reference/POSC_well_purpose.html,, Mineral test hole- any hole in excess of one hundred (100) feet drilled during the exploration for minerals but shall exclude auger drilling in surficial or otherwise unconsolidated material, drilling in conjunction with mining or quarrying

Term	Definition
	operations, and drill holes for the exploration of oil and/or gas, water, structural foundations, and seismic surveys. http://www.tennessee.gov/sos/rules/0950/0950-01-01.pdf
Mitigation	Lowing of the groundwater level to prevent the groundwater table to reach polluted sites or constructions.
MonitoringQuality	Most monitoring wells constructed today are used to assess the nature and distribution of pollutants and contaminants in groundwater. The nature and distribution of naturally occurring chemical constituents. Subsurface hydrologic conditions, and, hydraulic properties of strata as they relate to pollutant and contaminant movement.
Oil	An oil well is a term for any perforation through the Earth's surface designed to find and release both petroleum oil and gas hydrocarbons. http://en.wikipedia.org/wiki/Oil_well
OilExploratory	A exploratory well drilled in an unproved area to test for a new field, a new pay, a deeper reservoir, or a shallower reservoir. Also known as an exploration well. http://posc.org/technical/reference/POSC_well_purpose.html,, Exploratory Well: A well drilled with a high degree of risk to: A) search for a new reservoir of oil or gas, also known as a Wildcat, B) extend the parameters of an existing field known as a Step Out, C) to prove another zone within an already producing field. http://www.vastenergy.com/definitions.htm
pedological survey	Survey and characterization of soils, e.g. for agricultural purposes, ground water protection, etc.
Pollution monitoring (waste dumps, etc.)	The purpose is to monitor known pollution sites.
Recharge	a- Aquifer Recharge Wells (5R21) Used to recharge depleted aquifers and may inject fluids from a variety of sources such as lakes, streams, domestic wastewater treatment plants, other aquifers, etc. b- Saline Water Intrusion Barrier Wells (5B22) Used to inject water into fresh water aquifers to prevent intrusion of salt water into fresh water aquifers. Used in highly populated areas. c- Subsidence Control Wells (5S23) Used to inject fluids into a non-oil or gas-producing zone to reduce or eliminate subsidence associated with overdraft of fresh water and not used for the purpose of oil or natural gas production. a, b, c - http://www.epa.gov/Region2/water/compliance/wellclasstypetable_inventoryc_form.pdf
Remediation	Remediation in general.
Shallow methane production	Production of methane that originates from Quaternary deposits.
Shot hole	In connection with seismic surveys explosives are loaded into shot holes.
Sparging/Thermal cleaning	A kind of remediation. In situ cleaning of soil using heat (steam).
Water injection	The ground is used as a heat storage. For example could relative warmer used cooling water be injected in the summer and extracted in the winter.

BoreholeStartPointCode

Code list

Term	Definition
from pre-existing hole	New drill hole spudded off the wall of an existing hole
natural ground surface	drilling started from a natural topographic surface
open pit floor or wall	Drilling started from the wall of an open pit or quarry
underground	Drilling started from an underground location, such as a driveway, chamber or open-stope

CampaignType

Enumeration

Term	Definition
interpretation	
measurement	
processing	

CompositionCategory

Code list
(CGI_Term, Class: CompoundMaterial, Attribute: compositionCategory)

Term	Definition
Argillic	Greater than accessory amount (greater than 5 percent by volume) of clay is present
Arkosic detrital mode	Sandstone petrographic composition term indicating that detrital mode for clastic rock (Q-F-L) includes less than 75 percent quartz and the feldspar to lithic ratio is greater than 3 to 1. This corresponds to the arkose field of Folk (1968). For clastic rocks with little or no matrix and cement, rocks in this detrital mode composition category will also have quartz-feldspathic mineralogical composition.
Asphaltic	Material contains a significant amount of asphalt, which is “A dark brown to black viscous liquid or low-melting solid bitumen that consists almost entirely of carbon and hydrogen...[and] formed in oil-bearing rocks by the evaporation of volatiles...” (Jackson, 1997, p. 39).
Barium-bearing carbonate chemistry	CO3 is the predominant anion, and greater than 5 mole percent of cations are Ba.
Bioclastic	Carbonate sedimentary material contains significant broken skeletal material
Calcareous	Calcium carbonate minerals are present, carbonate minerals form less than 50 percent of rock, material contains sufficient CaCO3 to react forming bubbles when hydrochloric acid is applied.
Calcareous monomeralic carbonate	Carbonate minerals form greater than 75 percent of rock, and calcium carbonate minerals forms greater than 75 percent of carbonate minerals.
Calcium-rich carbonate chemistry	CO3 is the predominante anion, and the Ca is the most abundant (mole percent) cation.
Calcsilicate	Material consists of greater than or equal to 50 percent calcsilicate or carbonate minerals and carbonate minerals less than or equal to calcsilicate minerals in mineral mode.
Calcsilicate-bearing	Calcsilicate minerals of any sort are present, but less than 50 percent of rock
Carbonaceous	Material containing significant carbon or hydrocarbon mineral phases, including graphite, coal, oil, gas, lignite, peat.
Carbonaceous chemistry	Containing greater than 5 percent reduced carbon in compounds that are typically the diagenetic products of dead organisms (e.g. coal, bitumen and petroleum). 5 percent value is chosen for consistency with SLTTs usage of term carbonaceous.
Carbonate	Material consists of greater than 50 percent calcsilicate or carbonate minerals and carbonate minerals greater than calcsilicate minerals in mineral mode. Metacarbonate of NADMSC SLTTm (2004) terminology, adopted here for non-genetic use.
Carbonate bearing	Carbonate minerals of any sort are present, but less than 50 percent of rock.
Carbonate chemistry	The carbonate (CO3) anion is the predominant anion (by mole percent) in chemical analysis. Sub-categories may be defined by dominant cation. Material in this chemical class overlaps with the monomineralic carbonate class, and probably overlaps with the Carbonate class in the mineralogical composition classification.
Chloride chemistry	Chloride is the most abundant (mole percent) anion
Chloritic	Greater than accessory amount (greater than 5 percent by volume) of chlorite group minerals are present
Composition not	Composition not specified. Use in normative descriptions where any composition

Term	Definition
specified	property is allowed.
Dolomite monomineralic carbonate	Carbonate minerals form greater than 75 percent of rock, and dolomite forms greater than 75 percent of carbonate minerals.
Dolomitic	Dolomite is present, carbonate minerals form less than 50 percent of rock.
Feldspathic	Sedimentary material contains significant feldspar mineral content
Feldspathic detrital mode	General sandstone petrography term for a sandstone in which the ratio of feldspar to lithic fragments is greater than 1:1 and less than 75 percent quartz is present in the detrital mode. Subsumes lithic arkosic and arkosic sandstone petrographic composition classes. Usage of modifier feldspathic is consistent with petrographic subdivisions of Dott (1964) and Williams, Turner and Gilbert (1982)
Feldspathic lithic detrital mode	Sandstone petrographic composition term indicating that detrital mode for clastic rock (Q-F-L) includes less than 75 percent quartz and the feldspar to lithic ratio is between 1 to 1 and 1 to 3. This corresponds to the feldspathic litharenite field of Folk (1968). Rocks in this class are likely to be quartzo-feldspathic in terms of mineralogical composition terms in this vocablary, but because the mineralogical composition of the lithic fraction is not constrainged, this correlation is not necessary.
Ferromagnesian	Material consists of greater than 40 percent dark ferromagnesian silicate minerals. Standard term defined by Bates and Jackson (1987) to mean 'containing iron and magnesium'. Subsumes mafic and ultramafic.
Ferruginous	Greater than accessory amount (greater than 5 percent by volume) of non-silicate iron minerals (hematite, magnetite, siderite...) are present. Rocks containing abundant iron-rich silicate minerals would use the 'Ferromagnesian' terms.
Fluoride chemistry	Fluorine is the most abundant (mole percent) anion
Halide chemistry	One or more of halide group elements (F, Cl, Br, I) are most abundant (mole percent) anion
High silica chemistry	Containing 65 percent or more SiO2 by weight. Syn acid.
Impure calcsilicate or carbonate	Material consists of greater than 50 percent calcsilicate or carbonate minerals and relative proportion of calcsilicate and carbonate minerals is unknown or not specified.
Intermediate silica chemistry	Containing SiO2 in the range 52-65 percent, sometimes described as "intermediate" rocks.
Intraclastic	Carbonate sedimentary material contains signficant intraclast content
Iron-bearing carbonate chemistry	CO3 is the predominant anion, and iron is greater than 5 mole percent of the cations (includes Fe, Mg, Mn, Ba, Sr, Ca...).
Iron-rich carbonate chemistry	CO3 is the predominant anion, and iron is the most abundant (mole percent) cation
Lithic	Sedimentary material contains significant detrital rock fragments derived by erosion from older, pre-existing rock materials
Lithic arkosic detrital mode	Sandstone petrographic composition term indicating that detrital mode for clastic rock (Q-F-L) includes less than 75 percent quartz and the ratio of lithic fragments to feldspar is between 1:1 and 1:3. This corresponds to the lithic arkose field of Folk (1968); the 75 percent quartz boundary is chosen to be consistent with quartzsose composition as defined in the mineralogic compostion terms vocabulary. Because of the abundance of lithic fragments for which the mineralogic composition is not specified, and the presence of undiscernible matrix and cement that are not incuded in the detrital mode, corresondence with the mineralogical composition terms is very approximate.
Lithic detrital mode	Sandstone petrographic composition term indicating that detrital mode for clastic rock (Q-F-L) includes less than 75 percent quartz and the lithic to feldspar ratio is greater than 3 to 1. This corresponds to the litharenite field of Folk (1968). Because the mineralogy of the lithic fragments is not constrained, the mineralogical composition is largely independent of the detrital mode composition for this class.
Lithic rich detrital mode	Sandstone petrographic composition term indicating that the ratio of lithic fragments to feldspar is greater than 1:1, and less than 75 percent quartz is present in the detrital mode. Because the mineralogy of the lithic fragments is not constrained, the mineralogical composition is largely independent of the detrital

Term	Definition
	mode composition for this class.
Low silica chemistry	Containing SiO2 in the range 44-52 percent. Syn basic.
Mafic	Material consists of greater than or equal to 40 percent and less than 90 percent ferromagnesian silicate minerals.
Magnesium-rich carbonate chemistry	CO3 is the predominant anion, and Mg is the most abundant (mole percent) cation.
Metallic oxide bearing	Greater than accessory amounts (greater than 5 percent by volume) of base metal oxide minerals such as magnetite (Fe3O4) or pyrolusite (MnO2) are present.
Metaluminous	Chemical composition term used for igneous rocks, denoting that content of aluminum oxide is greater than sodium oxide plus potassium oxide, but aluminum oxide less than sum of Na, K and Ca oxide.
Micaceous	Greater than accessory amount (greater than 5 percent by volume) of mica group mineral are present
Mono mineralic	Greater than 75 percent of the material consists of a single mineral species.
Monomictic	Grains or clasts are composed of a single rock or mineral type (Jackson, 1997)
Monomineralic carbonate	Rock in which carbonate minerals form greater than 75 percent of rock.
Nitrate chemistry	Nitrate (NO3) is most abundant (mole percent) anion.
Other composition	Composition is known but doesn't' fit in any other category
Oxide	Material predominantly composed of oxide minerals
Pelitic	Material for which the sum of modal quartz+feldspar+ mica + aluminous mineral is greater than or equal to 70 percent, and aluminous mineral + mica content is greater than or equal to 40 percent.
Peralkaline	Aluminum oxide (Al2O3) is less than sum of K and Na oxide.
Peraluminous	Aluminum oxide (Al2O3) greater than sum of Na, K and Ca oxide.
Petroliferous	Crude oil or natural gas is present, generally in trace amounts, commonly detected by smell
Phosphate chemistry	Phosphate (PO4) is the most abundant (mole percent) anion.
Phosphatic	Greater than accessory amount (greater than 5 percent by volume) of phosphate minerals are present
Polymictic	Grains or clasts are composed of many mineral or rock types
Quartz-feldspar-pelitic	Material for which the sum of modal quartz+feldspar+ mica + aluminous mineral is greater than or equal to 70 percent.
Quartzo-feldspathic	Material for which the sum of modal quartz+feldspar+ mica + aluminous mineral is greater than or equal to 70 percent, and quartz + feldspar (sensu Robertson, 1999) greater than 60 percent.
Quartzose	Material consists of greater than or equal to 75 percent quartz.
Quartzose detrital mode	Detrital mineral grains in a granular rock consist of greater than 95 percent quartz. This petrographic criteria follows the most restrictive definition of the composition field at the quartz vertex of the sandstone QFL triangle (Folk, 1968). This use of term quartzose is more restrictive that that used in the mineralogical composition term vocabulary, reflecting the interpretive significance of pure quartz sandstones in sedimentary petrology.
Semi-pelitic	Material for which the sum of modal quartz+feldspar+ mica + aluminous mineral is greater than or equal to 70 percent, and quartz+ feldspar less than 60 percent
Silicate chemistry	Composed of minerals whose crystal structure contains SiO4 tetrahedra, either isolated or joined through one or more oxygen atoms to form groups, chains, sheets or three-dimensional structures with metallic cations. Composition ranges from 20-100 percent SiO2. Typically some Al substitutues for silica. A survey of chemical analyses in the Georock database (query FOR ALL GEOLOGICAL SETTINGS, MATERIAL: WHOLE ROCK (AND VOLCANIC GLASS), PUB. YEARS: 2005-1970), 10/10/2005 state, http://georoc.mpch-mainz.gwdg.de/georoc/Entry.html) discovered that the lowest silica (Si02) content for igneous rock is about 20 percent. This is consistent with the lowest silica content found for a silicate mineral is about 21 percent for a chlorite variety found by scanning the mineral analyses in Deer, Howie, and Zussman (1966).
Silicic	Greater than accessory amount (greater than 5 percent by volume) of silica,

Term	Definition
	amorphous, as quartz, or any of the silica polymorphs are present
Sub feldspathic detrital mode	Sandstone petrographic composition term indicating that detrital mode for clastic rock (Q-F-L) includes less than 50 percent lithic fragments, between 75 and 95 percent quartz (thus less than 25 percent feldspar). This corresponds to the subarkose field of Folk (1968); the 75 percent quartz boundary is consistent with the quartzsose composition as defined in the mineralogic compostion terms vocabulary, but if more than a few percent 'matrix' or cement is present, this is not necessarily equivalent to the mineralogical composition term.
Sub lithic detrital mode	Sandstone petrographic composition term indicating that detrital mode for clastic rock (Q-F-L) includes more than 50 percent lithic fragments, between 75 and 95 percent quartz (thus less than 25 percent feldspar). This corresponds to the sublitharenite field of Folk (1968); the 75 percent quartz boundary is consistent with quartzsose composition as defined in the mineralogic compostion terms vocabulary.
Subaluminous	Aluminum oxide within 10 percent of sum of Na and K oxide.
Sulfate	Material predominantly composed of sulfate minerals
Sulfate chemistry	Sulfate is the most abundant anion
Sulfide	Material predominantly composed of sulfide minerals
Sulfide bearing	Greater than accessory amount (greater than 5 percent by volume) of sulfide mineral are present
Sulfide chemistry	Sulfur is the most abundant anion; cations are metals or semimetals.
Sulfosalt chemistry	Sulfide in which a semimetal (As, Sb, Bi) is present in a cation role
Ultramafic	Material consists of greater than 90 percent ferromagnesian silicate minerals..
Very low silica chemistry	Containing between about 20 and 44 percent SiO2. A survey of chemical analyses in the Georock database (query FOR ALL GEOLOGICAL SETTINGS, MATERIAL: WHOLE ROCK (AND VOLCANIC GLASS), PUB. YEARS: 2005-1970), 10/10/2005 state, http://georoc.mpch-mainz.gwdg. syn ultrabasic.
Volcanic lithic	Sedimentary material contains significant broken volcanic rock fragments or vitric fragments, irrespective of their pyroclastic or epiclastic origin.

CompositionPartRoleTerm

Code list

Term	Definition
Bed lithosome	Lithosome in lithostratigraphic unit that occurs as individual beds interleaved with other constituents on the outcrop (m) scale or larger.
Blocks	Geologic unit constituent is present as masses with generally sharp boundaries and block-like geometry within a matrix of some other material emplaced by processes at the earth's surface--e.g. volcanic eruption or mass wasting. Implication is that blocks were derived from the same source geologic unit and emplaced in the described unit.
Concretion	Hard, compact mass or aggregate of mineral matter, normally subsperical but commonly oblate, disc-shaped or irregular. Formed from precipitation from solution about a nucleus or centre. Use as a geologic unit part should be restricted to concretions that are too large to consider as constituents in the rock material that composes the unit.
Cyclic bedding package	Lithosome characterized by an internal sequence of units, which is repeated in a stacked sequence; e.g. fining-upward sequence, thickening upward sequence, bouma sequence.
Enclave	General term for a polymineralic aggregate enclosed in a granitoid.
Facies	Represents a particular body of rock that is a lateral variant of a lithostratigraphic unit, or a variant of a lithodemic unit. Contrast with lithosome in being a particular, connected body of rock, as opposed to a kind of rock body that is repeated in many places in a unit.
Geologic unit matrix	Lithosome in a geologic unit that is generally interstitial to other constituents, e.g. in a mass wasting deposit, melange, tuff breccia.

Term	Definition
Inclusion	Geologic unit constituent is present as masses with generally sharp boundaries enclosed within a matrix of some other material.
Irregular lithosome	lithosome in a mixed/heterogeneous lithodemic unit that occurs in irregular bodies within unit
Layer lithosome	lithosome in igneous or metamorphic geologic unit that occurs as layers alternating with other constituents.
Lenticular lithosome	lithosome occurs as discrete lense-shaped bodies, not connected with other bodies.
Lithosome	A kind of rock body that has multiple occurrences in a single geologic unit. A mass of rock of uniform character, characterized by geometry, composition, and internal structure. Generally denotes rock mass that is the product of a particular rock forming process or related sequence of processes in the containing unit. Example--bouma sequence, point bar sequence. A particular lithosome may be characterized by the presence of blocks, but blocks are not treated as kinds of lithosome because the internal character of the blocks is determined by a separate genetic sequence from the described unit. This vocabulary generalizes the concept defined in Neuendorf et al 2005 to include bodies of igneous or metamorphic rock as well as sedimentary rock. NADM SLTTs (2004) used the term 'lithotope' with similar meaning for sedimentary rocks.
Marker bed	Stratigraphic part that is a thin laterally continuous bed within another unit.
Only part	entire described unit consists of a single part or constituent
Part of	The geologic unit part role is not known in any greater detail. Inclusion of Only_part as a separate concept implies that this concept is the equivalent of 'proper part' in mereology.
Pendants	A block of wall rock material in an igneous intrusion. Pendants become xenoliths as the dimension becomes smaller than about 10 m in their longest dimension. Although term pendant has connotation of being suspended or supported from above, this is rarely demonstrable in geologic situations, and the concept here does not require connection to the wall of the containing intrusion.
Rafts	Pendants of pre-intrusive country rock in intrusive igneous matrix that have large horizontal extent relative to their thickness
Roof pendant	Pendant that is demonstrably derived from the upper boundary of an igneous body.
Screen	Pendant that is a vertical sheet like pendant in an intrusive igneous rock body.
Stratigraphic part	A geologic unit part that occupies a particular stratigraphic position within a geologic unit. Part is a particular body of rock.
Tectonic block	The geologic unit part occurs as discrete masses with faulted boundaries, emplaced into the host unit by tectonic processes inside the earth, e.g. blocks in tectonic melange
Unspecified part role	Geologic unit part with unspecified role; use in normative descriptions when any role is allowed.
Vein or dike lithosome	Lithosome occurs as intrusive, sheet-like bodies within the unit as an essential part of the unit.
Xenolith	Inclusion of pre-intrusive country rock in intrusive igneous matrix, cm to about 10 meter diameter in longest dimension. Use term pendant for larger blocks.

ConsolidationDegree

Code list
(CGI_Term, Class: RockMaterial, Attribute: consolidationDegree)

Term	Definition
Consolidated	Particulate constituents of a compound material adhere to each other strongly enough that the aggregate can be considered a solid material in its own right.
Consolidation not specified	In normative descriptions, indicates that consolidation state is not a determining factor in identification, it may have any value.
Consolidation variable	Consolidation ranges from unconsolidated to indurated on scale of description

Term	Definition
Incipient consolidation	Shoveled with difficulty; relative density 0.4 - 0.7.
Indurated	Requires blasting or heavy equipment to loosen; Relative density 0.9-1.0. Rings to blow of hammer.
Moderately indurated	Multiple blows with standard rock hammer (less than 1 kg) are required to break rock.
Slightly indurated	Rock can be broken with single blow from standard rock hammer (less than 1 kg mass).
Unconsolidated	Particulate constituents of a compound material do not adhere to each other strongly enough that the aggregate can be considered a solid in its own right.
Unconsolidated, loose	Easily shoveled, can be indented with fingers; Relative density 0.2-0.4.
Unconsolidated, very loose	Easily indented with fingers; Relative density 0.0-0.2.
Variable induration	Material is lithified, but induration varies at scale of description.
Well consolidated	Requires pick to loosen for shoveling; relative density 0.7-0.9.
Well indurated	Particles in the rock are strongly bound together such that rock surface can only be broken with great difficulty using standard rock hammer (less than 1 kg mass).

ConventionCode

Code list

Term	Definition
Dip Dip Direction	The orientation measurement consists of a dip and a dip direction. Dip is the angle that the structural surface (eg bedding, fault plane) makes with the horizontal measured perpendicular to the strike of the structure and in the vertical plane Dip direction is the azimuth perpindicular to the strike of the structure
Strike Dip RHR	The strike and dip of planar data is listed according to the 'right-hand rule' or, as one looks along the strike direction, the surface dips to the right. Dip is the angle that the structural surface (eg bedding, fault plane) makes with the horizontal measured perpindicular to the strike of the structure and in the vertical plane

CurveModelTypeValue

Code list

Term	Definition
boreholeLog	Borehole log. -- Description -- Distribution of geophysical properties along a borehole
layerModel	Layer model -- Description -- Geophysical properties in a sequence of infinite layers. Results are represented as line coverage along a straight line perpendicular to the layer boundaries, starting from the location of measurement, ending at the depth of penetration.

DataSetTypeValue

Code list

Term	Definition
2DSeismicSurvey	2D seismic survey
3DSeismicSurvey	3D seismic survey
airborneGeophysicalSurvey	Airborne geophysical survey
boreholeLoggingSurvey	Borehole logging survey
gravitySurvey	Gravity survey

Term	Definition
magneticSurvey	Magnetic measurement survey

DeformationStyleTerm

Code list

Term	Definition
brittle	brittle (fault, breccia)
brittle-ductile	brittle-ductile
ductile	ductile (shear)
unknown	unknown

DescriptionPurpose

Code list

Term	Definition
definingNorm	A description that specifies properties sufficient to identify a new occurrence as belonging to the class represented by the description. Basically these are the 'sufficient conditions' for class membership. Used when presented with a query 'I have an outcrop with these properties; which geologic unit should I assign to the outcrop?' DefiningNorm has to do with the intension of a ControlledConcept.
instance	A description that is specific to a particular observed occurrence. This is 'raw data', and its classification may start out as very general. There are kinds of narrowly defined ControlledConcepts that might not allow 'instances' that are different from the DefiningNorm. It might be worth considering a different relationship between MappedFeature and an Instance GeologicEntity, with the GeologicEntity role being 'description'.
typicalNorm	A description that specifies properties to be expected of some occurrence associated with the GeologicEntity. This description may include many properties that are not part of the DefiningNorm. For example, the fact that granite is typically light-colored is not a defining property, but is certainly a useful typical property. These kinds of descriptions would be used to address queries like 'This area is within a polygon classified as Podunk Formation; what sort of lithology am I most likely to encounter when I start digging?' The Podunk Formation may be defined by the presence of a certain ammonite... TypicalNorm description would be constructed as a summary over many Instance descriptions.

DeterminationMethodTerm

Code list

Term	Definition
Calculated average orientation	Orientation value is specified using a calculated average of a collection of related orientations (computer generalization).
Estimate from air photo	Orientation of a geologic structure estimated based on inspection or measurements on an air photograph.
Estimate from distance	Orientation of a geologic structure based on observation from a distance great enough to preclude direct inspection of the structure to determine orientation.
Measure on outcrop	Orientation of surface or line is measured on an outcrop of that surface or line directly, e.g. by measuring a particular bedding surface, a 3-D exposure of a fold hinge, a particular stretched mineral grain in a foliation surface.
Method unknown	use value qualifier to specify the kind of nil
Photogeologic determination	Orientation determined based on measurements from aerial photography or satellite imagery (in conjunction with an elevation model.

Term	Definition
Standard on site measure	Orientation measured using compass or other instrument directly on or at an outcrop of the structure.
Three point determination	Orientation determined by fitting a plane to three or more points located on the geologic surface of interest.
Visual surface estimation on outcrop	Orientation of a surface is measured by visually averaging across one or more outcrops in a small area--e.g. approximating dip by looking down strike of beds, approximating strike by outcrop trace of one or more beds.

EventEnvironment

Code list
(CGI_Term, Class: GeologicEvent, Attribute: eventEnvironment)

Term	Definition
Abandoned river channel setting	A drainage channel along which runoff no longer occurs, as on an alluvial fan
Above carbonate compensation depth setting	Marine environment in which carbonate sediment does not dissolve before reaching the sea floor and can accumulate.
Abyssal setting	The ocean environment at water depths between 3,500 and 6,000 metres
Active continental margin setting	Plate margin setting on continental crust.
Active spreading center setting	Divergent plate margin at which new oceanic crust is being formed
Aeolian process setting	Sedimentary setting in which wind is the dominant process producing, transporting, and depositing sediment. Typically has low-relief plain or piedmont slope physiography.
Algal flat setting	Modern "algal flats are found on rock or mud in areas flooded only by the highest tides and are often subject to high evaporation rates. Algal flats survive only when an area is salty enough to eliminate snails and other herbivorous animals that eat algae, yet is not so salty that the algae cannot survive. The most common species of algae found on algal flats are blue-green algae of the genera Scytonema and Schizothrix. These algae can tolerate the daily extremes in temperature and oxygen that typify conditions on the flats. Other plants sometimes found on algal flats include one-celled green algae, flagellates, diatoms, bacteria, and isolated scrubby red and black mangroves, as well as patches of saltwort. Animals include false cerith, cerion snails, fiddler crabs, and great land crabs. Flats with well developed algal mats are restricted for the most part to the Keys, with Sugarloaf and Crane Keys offering prime examples of algal flat habitat." (Audubon, 1991)
Alluvial fan setting	A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream (esp. in a semiarid region) at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or wherever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases; it is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with gradually decreasing gradient
Alluvial plain setting	An assemblage landforms produced by alluvial and fluvial processes (braided streams, terraces, etc.,) that form low gradient, regional ramps along the flanks of mountains and extend great distances from their sources (e.g., High Plains of North America). (NRCS GLOSSARY OF LANDFORM AND GEOLOGIC TERMS). A level or gently sloping tract or a slightly undulating land surface produced by extensive deposition of alluvium... Synonym-- wash plain;...river plain; aggraded valley plain;... (Jackson, 1997, p. 17). May include one or more River plain systems.
Anoxic setting	Setting depleted in oxygen, typically subaqueous.
Arid or Semi Arid	Setting characterized by mean annual precipitation of 10 inches (25 cm) or less.

Term	Definition
environment setting	(Jackson, 1997, p. 172). Equivalent to SLTT 'Desert setting', but use 'Arid' to emphasize climatic nature of setting definition.
Back arc setting	Tectonic setting adjacent to a volcanic arc formed above a subduction zone. The back arc setting is on the opposite side of the volcanic arc from the trench at which oceanic crust is consumed in a subduction zone. Back arc setting includes terrane that is affected by plate margin and arc-related processes.
Backreef setting	The landward side of a reef. The term is often used adjectivally to refer to deposits within the restricted lagoon behind a barrier reef, such as the "back-reef facies" of lagoonal deposits. In some places, as on a platform-edge reef tract, "back reef" refers to the side of the reef away from the open sea, even though no land may be nearby
Barrier beach setting	A narrow, elongate sand or gravel ridge rising slightly above the high-tide level and extending generally parallel with the shore, but separated from it by a lagoon (Shepard, 1954, p.1904), estuary, or marsh; it is extended by longshore transport and is rarely more than several kilometers long.
Barrier island coastline setting	setting meant to include all the various geographic elements typically associated with a barrier island coastline, including the barrier islands, and geomorphic/geographic elements that are linked by processes associated with the presence of the island (e.g. wash over fans, inlet channel, back barrier lagoon).
Barrier lagoon setting	A lagoon that is roughly parallel to the coast and is separated from the open ocean by a strip of land or by a barrier reef. Tidal influence is typically restricted and the lagoon is commonly hypersaline.
Basin bog setting	An ombrotrophic or ombrogene peat/bog whose nutrient supply is exclusively from rain water (including snow and atmospheric fallout) therefore making nutrients extremely oligotrophic
Basin plain setting	Near flat areas of ocean floor, slope less than 1:1000; generally receive only distal turbidite and pelagic sediments.
Bathyal setting	The ocean environment at water depths between 200 and 3500 metres
Beach setting	The unconsolidated material at the shoreline that covers a gently sloping zone, typically with a concave profile, extending landward from the low-water line to the place where there is a definite change in material or physiographic form (such as a cliff), or to the line of permanent vegetation (usually the effective limit of the highest storm waves); at the shore of a body of water, formed and washed by waves or tides, usually covered by sand or gravel, and lacking a bare rocky surface.
Below carbonate compensation depth setting	Marine environment in which water is deep enough that carbonate sediment goes into solution before it can accumulate on the sea floor.
Biological reef setting	A ridgelike or moundlike structure, layered or massive, built by sedentary calcareous organisms, esp. corals, and consisting mostly of their remains; it is wave-resistant and stands topographically above the surrounding contemporaneously deposited sediment.
Blanket bog	Topogeneous bog/peat whose moisture content is largely dependent on surface water. It is relatively rich in plant nutrients, nitrogen, and mineral matter, is mildly acidic to nearly neutral, and contains little or no cellulose; forms in topographic depressions with essential stagnat or non-moving minerotrophic water supply
Bog setting	Waterlogged, spongy ground, consisting primarily of mosses, containing acidic, decaying vegetation that may develop into peat.
Braided river channel setting	A stream that divides into or follows an interlacing or tangled network of several small branching and reuniting shallow channels separated from each other by ephemeral branch islands or channel bars, resembling in plan the strands of a complex braid. Such a stream is generally believed to indicate an inability to carry all of its load, such as an overloaded and aggrading stream flowing in a wide channel on a floodplain
Carbonate dominated shoreline setting	A shoreline setting in which terrigenous input is minor compared to local carbonate sediment production. Constructional biogenic activity is an important element in geomorphic development.
Cave setting	A natural underground open space; it generally has a connection to the surface, is

Term	Definition
	large enough for a person to enter, and extends into darkness. The most common type of cave is formed in limestone by dissolution.
Coastal dune field setting	A dune field on low-lying land recently abandoned or built up by the sea; the dunes may ascend a cliff and travel inland.
Coastal plain setting	A low relief plain bordering a water body extending inland to the nearest elevated land, sloping very gently towards the water body. Distinguished from alluvial plain by presence of relict shoreline-related deposits or morphology.
Collisional setting	Tectonic setting in which two continental crustal plates impact and are sutured together after intervening oceanic crust is entirely consumed at a subduction zone separating the plates. Such collision typically involves major mountain forming events, exemplified by the modern Alpine and Himalayan mountain chains.
Contact metamorphic setting	Metamorphism of country rock at the contact of an igneous body.
Continental borderland setting	An area of the continental margin between the shoreline and the continental slope that is topographically more complex than the continental shelf. It is characterized by ridges and basins, some of which are below the depth of the continental shelf. An example is the southern California continental borderland;.... (Jackson, 1997, p. 138)..
Continental rift setting	Extended terrane in a zone of continental breakup, may include incipient oceanic crust. Examples include Red Sea, East Africa Rift, Salton Trough
Continental shelf setting	That part of the ocean floor that is between the shoreline and the continental slope (or, when there is no noticeable continental slope, a depth of 200 m). It is characterized by its gentle slope of 0.1 degree (Jackson, 1997, p. 138). Continental shelves have a classic shoreline-shelf-slope profile termed 'clinoform'.
Continental-crustal setting	That type of the Earth's crust which underlies the continents and the continental shelves; it is equivalent to the sial and continental sima and ranges in thickness from about 25 km to more than 70 km under mountain ranges, averaging ~40 km. The density of the continental crust averages ~2.8 g/cm3 and is ~2.7 g.cm3 in the upper layer. The velocities of compressional seismic waves through it average ~6.5 km/s and are less than ~7.0 km/sec.
Crustal setting	The outermost layer or shell of the Earth, defined according to various criteria, including seismic velocity, density and composition; that part of the Earth above the Mohorovicic discontinuity, made up of the sial and the sima.
Cutoff meander setting	The abandoned, bow- or horseshoe-shaped channel of a former meander, left when the stream formed a cutoff across a narrow meander neck. Note that these are typically lakes, thus also lacustrine.
Deep sea trench setting	Deep ocean basin with steep (average 10 degrees) slope toward land, more gentle slope (average 5 degrees) towards the sea, and abundant seismic activity on landward side of trench. Does not denote water depth, but may be very deep.
Delta distributary channel setting	A divergent stream flowing away from the main stream and not returning to it, as in a delta or on an alluvial plain
Delta distributary mouth setting	The mouth of a delta distributary channel where fluvial discharge moves from confined to unconfined flow conditions
Delta front setting	A narrow zone where deposition in deltas is most active, consisting of a continuous sheet of sand, and occurring within the effective depth of wave erosion (10 m or less). It is the zone separating the prodelta from the delta plain, and it may or may not be steep"
Delta plain setting	The level or nearly level surface composing the landward part of a large or compound delta; strictly, an alluvial plain characterized by repeated channel bifurcation and divergence, multiple distributary channels, and interdistributary flood basins
Deltaic system setting	Environments at the mouth of a river or stream that enters a standing body of water (ocean or lake). The delta forms a triangular or fan-shaped plain of considerable area. Subaerial parts of the delta are crossed by many distributaries of the main river, and commonly extend beyond the general trend of the coast. Subaqueous parts of the delta merge with the adjacent basin floor, and are progressively influenced by non-fluvial processes. Deltas result from the accumulation of sediment supplied by the river in such quantities that it is not

Term	Definition
	removed by tides, waves, and currents. Adapted from the Glossary of Geology definition for delta (Jackson, 1997, p. 167).
Dunefield setting	Extensive deposits on sand in an area where the supply is abundant. As a characteristic, individual dunes somewhat resemble barchans but are highly irregular in shape and crowded; erg areas of the Sahara are an example.
Earth interior setting	Geologic environments within the solid Earth.
Earth surface setting	Geologic environments on the surface of the solid Earth. Hierarchy presented here is based on assumption that a particular setting may be specified by a combination of a climatic setting with one or more process or geomorphically defined settings..
Englacial setting	Contained, embedded, or carried within the body of a glacier or ice sheet; said of meltwater streams, till, drift, moraine
Epicontinental marine setting	Marine setting situated within the interior of the continent, rather than at the edge of a continent.
Estuarine delta setting	A delta that has filled, or is in the process of filling, an estuary
Estuarine lagoon setting	A lagoon produced by the temporary sealing of a river estuary by a storm barrier. Such lagoons are usually seasonal and exist until the river breaches the barrier; they occur in regions of low or spasmodic rainfall
Estuary setting	Environments at the seaward end or the widened funnel-shaped tidal mouth of a river valley where fresh water comes into contact with seawater and where tidal effects are evident (adapted from Glossary of Geology, Jackson, 1997, p. 217).
Extended terrane setting	Tectonic setting characterized by extension of the upper crust, manifested by formation of rift valleys or basin and range physiography, with arrays of low to high angle normal faults. Modern examples include the North Sea, East Africa, and the Basin and Range of the North American Cordillera. Typically applied in continental crustal settings.
Extra-terrestrial setting	Material originated outside of the Earth or its atmosphere.
Fast spreading center setting	Spreading center at which the opening rate is greater than 100 mm per year.
Floodplain setting	The surface or strip of relatively smooth land adjacent to a river channel, constructed by the present river in its existing regimen and covered with water when the river overflows its banks. It is built of alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current. A river has one floodplain and may have one or more terraces representing abandoned floodplains
Forearc setting	Tectonic setting between a subduction-related trench and a volcanic arc
Foreland setting	The exterior area of an orogenic belt where deformation occurs without significant metamorphism. Generally the foreland is closer to the continental interior than other portions of the orogenic belt are.
Forereef setting	The seaward side of a reef; the slope covered with deposits of coarse reef talus
Gibber plain setting	A desert plain strewn with wind-abraded pebbles, or gibbers; a gravelly desert.
Glacial outwash plain setting	Areas adjacent to glacial front dominated by sediment and water supplied by glacial melting.
Glacier lateral setting	Settings adjacent to edges of confined glacier.
Glacier related setting	Earth surface setting with geography defined by spatial relationship to glaciers (e.g. on top of a glacier, next to a glacier, in front of a glacier...). Processes related to moving ice dominate sediment transport and deposition and landform development. Includes subaqueous, shoreline, and terrestrial settings that are impacted by the presence of glaciers. Considered a geographically defined setting in that a glacier is a geographic feature.
Glacier terminus setting	Region of sediment deposition due to melting of glacier ice. ablation and flow till setting.
Hadal setting	The deepest oceanic environment, i.e., over 6,000 m in depth. Always in deep sea trench.
High pressure low temperature Earth interior setting	High pressure environment characterized by geothermal gradient significantly lower than standard continental geotherm; enviornment in which blueschist facies metamorphic rocks form. Typically associated with subduction zones.

Term	Definition
Hillslope setting	Earth surface setting characterized by surface slope angles high enough that gravity alone becomes a significant factor in geomorphic development, as well as base-of-slope areas influenced by hillslope processes. Hillslope activities include creep, sliding, slumping, falling, and other downslope movements caused by slope collapse induced by gravitational influence on earth materials. May be subaerial or subaqueous.
Hinterland tectonic setting	Tectonic setting in the internal part of an orogenic belt, characterized by plastic deformation of rocks accompanied by significant metamorphism, typically involving crystalline basement rocks. Typically denotes the most structurally thickened part of an orogenic belt, between a magmatic arc or collision zone and a more 'external' foreland setting.
Hot spot setting	Setting in a zone of high heat flow from the mantle. Typically identified in intraplate settings, but hot spot may also interact with active plate margins (Iceland...). Includes surface manifestations like volcanic center, but also includes crust and mantle manifestations as well.
Humid temperate climatic setting	Setting with seasonal climate having hot to cold or humid to arid seasons.
Humid tropical climatic setting	Setting with hot, humid climate influenced by equatorial air masses, no winter season.
Hypabyssal setting	Igneous environment close to the Earth's surface, characterized by more rapid cooling than plutonic setting to produce generally fine-grained intrusive igneous rock that is commonly associated with co-magmatic volcanic rocks.
Inactive spreading center setting	Setting on oceanic crust formed at a spreading center that has been abandoned.
Inner neritic setting	The ocean environment at depths between low tide level and 30 metres
Interdistributary bay setting	A pronounced indentation of the delta front between advancing stream distributaries, occupied by shallow water, and either open to the sea or partly enclosed by minor distributaries
Intertidal setting	Pertaining to the benthic ocean environment or depth zone between high water and low water; also, pertaining to the organisms of that environment
Intraplate tectonic setting	Tectonically stable setting far from any active plate margins.
Lacustrine delta setting	The low, nearly flat, alluvial tract of land at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable area, crossed by many distributaries of the main river, perhaps extending beyond the general trend of the lake shore, resulting from the accumulation of sediment supplied by the river in such quantities that it is not removed by waves or currents. Most deltas are partly subaerial and partly below water.
Lacustrine setting	Setting associated with a lake. Always overlaps with terrestrial, may overlap with subaerial, subaqueous, or shoreline.
Lagoonal setting	A shallow stretch of salt or brackish water, partly or completely separated from a sea or lake by an offshore reef, barrier island, sand or spit (Jackson, 1997). Water is shallow, tidal and wave-produced effects on sediments; strong light reaches sediment..
Low energy shoreline setting	Settings characterized by very low surface slope and proximity to shoreline. Generally within peritidal setting, but characterized by low surface gradients and generally low-energy sedimentary processes.
Low pressure high temperature setting	Setting characterized by temperatures significantly higher that those associated with normal continental geothermal gradient.
Lower bathyal setting	The ocean environment at depths between 1000 and 3500 metres
Lower continental-crustal setting	Continental crustal setting characterized by upper amphibolite to granulite facies metamorphism, insitu melting, residual anhydrous metamorphic rocks, and ductile flow of rock bodies.
Lower delta plain setting	The part of a delta plain which is penetrated by saline water and is subject to tidal processes
Lower mantle setting	That part of the mantle that lies below a depth of about 660 km. With increasing depth, density increases from ~4.4 g/cm3-to ~5.6 g/cm3, and velocity of compressional seismic waves increases from ~10.7 km/s to ~13.7 km/s

Term	Definition
	(Dziewonski and Anderson, 1981).
Lower oceanic-crustal setting	Setting characterized by dominantly intrusive mafic rocks, with sheeted dike complexes in upper part and gabbroic to ultramafic intrusive or metamorphic rocks in lower part.
Mantle setting	The zone of the Earth below the crust and above the core, which is divided into the upper mantle and the lower mantle, with a transition zone separating them.
Marginal marine sabkha setting	Setting characterized by arid to semi-arid conditions on restricted coastal plains mostly above normal high tide level, with evaporite-saline mineral, tidal-flood, and eolian deposits. Boundaries with intertidal setting and non-tidal terrestrial setting are gradational. (Jackson, 1997, p. 561).
Marine carbonate platform setting	A shallow submerged plateau separated from continental landmasses, on which high biological carbonate production rates produce enough sediment to maintain the platform surface near sea level. Grades into atoll as area becomes smaller and ringing coral reefs become more prominent part of the setting.
Marine setting	Setting characterized by location under the surface of the sea.
Meandering river channel setting	Produced by a mature stream swinging from side to side as it flows across its floodplain or shifts its course laterally toward the convex side of an original curve
Medium-rate spreading center setting	Spreading center at which the opening rate is between 50 and 100 mm per year.
Mid ocean ridge setting	Ocean highland associated with a divergent continental margin (spreading center). Setting is characterized by active volcanism, locally steep relief, hydrothermal activity, and pelagic sedimentation.
Middle bathyal setting	The ocean environment at water depths between 600 and 1000 metres
Middle continental crust setting	Continental crustal setting characterized by greenschist to upper amphibolite facies metamorphism, plutonic igneous rocks, and ductile deformation.
Middle neritic setting	The ocean environment at depths between 30 and 100 metres
Mud flat setting	A relatively level area of fine grained material (e.g. silt) along a shore (as in a sheltered estuary or chenier-plain) or around an island, alternately covered and uncovered by the tide or covered by shallow water, and barren of vegetation. Includes most tidal flats, but lacks denotation of tidal influence..
Neritic setting	The ocean environment at depths between low-tide level and 200 metres, or between low-tide level and approximately the edge of the continental shelf
Ocean highland setting	Broad category for subaqueous marine settings characterized by significant relief above adjacent sea floor.
Oceanic plateau setting	Region of elevated ocean crust that commonly rises to within 2-3 km of the surface above an abyssal sea floor that lies several km deeper. Climate and water depths are such that a marine carbonate platform does not develop.
Oceanic-crustal setting	That type of the Earth's crust which underlies the ocean basins. The oceanic crust is 5-10 km thick; it has a density of 2.9 g/cm3, and compressional seismic-wave velocities travelling through it at 4-7.2 km/sec. Setting in crust produced by submarine volcanism at a mid ocean ridge.
Outer neritic setting	The ocean environment at depths between 100 and 200 metres or between low-tide level and approximately the edge of the continental shelf
Passive continental margin setting	Boundary of continental crust into oceanic crust of an oceanic basin that is not a subduction zone or transform fault system. Generally is rifted margin formed when ocean basin was initially formed.
Pediment setting	A gently sloping erosional surface developed at the foot of a receding hill or mountain slope. The surface may be essentially bare, exposing earth material that extends beneath adjacent uplands; or it may be thinly mantled with alluvium and colluvium, ultimately in transit from upland front to basin or valley lowland. In hill-foot slope terrain the mantle is designated "pedisediment." The term has been used in several geomorphic contexts: Pediments may be classed with respect to (a) landscape positions, for example, intermontane-basin piedmont or valley-border footslope surfaces (respectively, apron and terrace pediments (Cooke and Warren, 1973)); (b) type of material eroded, bedrock or regolith; or (c) combinations of the above. Compare - Piedmont slope..
Piedmont slope system setting	Location on gentle slope at the foot of a mountain; generally used in terms of intermontane-basin terrain. Main components include: (a) An erosional surface on

Term	Definition
	bedrock adjacent to the receding mountain front (pediment, rock pediment); (b) A constructional surface comprising individual alluvial fans and interfan valleys, also near the mountain front; and (c) A distal complex of coalescent fans (bajada), and alluvial slopes without fan form. Piedmont slopes grade to basin-floor depressions with alluvial and temporary lake plains or to surfaces associated with through drainage.
Plate margin setting	Tectonic setting at the boundary between two tectonic plates.
Plate spreading center setting	Tectonic setting where new oceanic crust is being or has been formed at a divergent plate boundary. Includes active and inactive spreading centers.
Playa setting	The usually dry and nearly level plain that occupies the lowest parts of closed depressions, such as those occurring on intermontane basin floors. Temporary flooding occurs primarily in response to precipitation-runoff events.
Polar climatic setting	Setting with climate dominated by temperatures below the freezing temperature of water. Includes polar deserts because precipitation is generally scant at high latitude. Climate controlled by arctic air masses, cold dry environment with short summer.
Prodelta setting	The part of a delta that is below the effective depth of wave erosion, lying beyond the delta front, and sloping gently down to the floor of the basin into which the delta is advancing and where clastic river sediment ceases to be a significant part of the basin-floor deposits; it is entirely below the water level
Proglacial setting	Immediately in front of or just beyond the outer limits of a glacier or ice sheet, generally at or near its lower end; said of lakes, streams, deposits, and other features produced by or derived from the glacier ice
Reef flat setting	A stony platform of
Regional metamorphic setting	Metamorphism not obviously localized along contacts of igneous bodies; includes burial metamorphism and ocean ridge metamorphism
River channel setting	The bed where a natural body of surface water flows or may flow; a natural passageway or depression of perceptible extent containing continuously or periodically flowing water, or forming a connecting link between two bodies of water; a watercourse
River plain system setting	Geologic setting dominated by a river system; river plains may occur in any climatic setting. Includes active channels, abandoned channels, levees, oxbow lakes, flood plain. May be part of an alluvial plain that includes terraces composed of abandoned river plain deposits.
Rocky coast setting	Shoreline with significant relief and abundant rock outcrop.
Sand plain setting	A sand-covered plain dominated by aeolian processes.
Seamount setting	Setting that consists of a conical mountain on the ocean floor (guyot). Typically characterized by active volcanism, pelagic sedimentation. If the mountain is high enough to reach the photic zone, carbonate production may result in reef building to produce a carbonate platform or atoll setting.
Shoreline settings	Geologic settings characterized by location adjacent to the ocean or a lake. A zone of indefinite width (may be many kilometers), bordering a body of water that extends from the water line inland to the first major change in landform features. Includes settings that may be subaerial, intermittently subaqueous, or shallow subaqueous, but are intrinsically associated with the interface between land areas and water bodies.
Slope-rise setting	The part of a subaqueous basin that is between a bordering shelf setting, which separate the basin from an adjacent landmass, and a very low-relief basin plain setting.
Slow spreading center setting	Spreading center at which the opening rate is less than 50 mm per year.
Strandplain setting	A prograded shore built seaward by waves and currents, and continuous for some distance along the coast. It is characterized by subparallel beach ridges and swales, in places with associated dunes.
Subaerial setting	Setting at the interface between the solid earth and the atmosphere, includes some shallow subaqueous settings in river channels and playas. Characterized by conditions and processes, such as erosion, that exist or operate in the open air on or immediately adjacent to the land surface

Term	Definition
Subaqueous setting	Setting situated in or under permanent, standing water. Used for marine and lacustrine settings, but not for fluvial settings.
Subduction zone setting	Tectonic setting at which a tectonic plate, usually oceanic, is moving down into the mantle beneath another overriding plate.
Subglacial setting	Formed or accumulated in or by the bottom parts of a glacier or ice sheet; said of meltwater streams, till, moraine, etc.
Submarine fan setting	Large fan-shaped cones of sediment on the ocean floor, generally associated with submarine canyons that provide sediment supply to build the fan..
Supraglacial setting	Carried upon, deposited from, or pertaining to the top surface of a glacier or ice sheet; said of meltwater streams, till, drift, etc. (Jackson, 1997, p. 639). Dreimanis (1988, p. 39) recommendation that supraglacial supersede superglacial is followed.
Supratidal setting	Pertaining to the shore area marginal to the littoral zone, just above high-tide level
Swamp or marsh setting	A water-saturated, periodically wet or continually flooded area with the surface not deeply submerged, essentially without the formation of peat. Marshes are characterized by sedges, cattails, rushes, or other aquatic and grasslike vegetation. Swamps are characterized by tree and brush vegetation.
Tectonically defined setting	Setting defined by relationships to tectonic plates on or in the Earth.
Terrestrial setting	Setting characterized by absence of direct marine influence. Most of the subaerial settings are also terrestrial, but lacustrine settings, while terrestrial, are not subaerial, so the subaerial settings are not included as subcategories.
Tidal channel setting	A major channel followed by the tidal currents, extending from offshore into a tidal marsh or a tidal flat.
Tidal flat setting	An extensive, nearly horizontal, barren tract of land that is alternately covered and uncovered by the tide, and consisting of unconsolidated sediment (mostly mud and sand). It may form the top surface of a deltaic deposit.
Tidal marsh setting	A marsh bordering a coast (as in a shallow lagoon or sheltered bay), formed of mud and of the resistant mat of roots of salt-tolerant plants, and regularly inundated during high tides; a marshy tidal flat.
Tidal setting	Setting subject to tidal processes
Transform plate boundary setting	Plate boundary at which the adjacent plates are moving laterally relative to each other.
Transitional-crustal setting	Crust formed in the transition zone between continental and oceanic crust, during the history of continental rifting that culminates in the formation of a new ocean.
Ultra high pressure crustal setting	Setting characterized by pressures characteristic of upper mantle, but indicated by mineral assemblage in crustal composition rocks.
Upper bathyal setting	The ocean environment at water depths between 200 and 600 metres
Upper continental crustal setting	Continental crustal setting dominated by non metamorphosed to low greenschist facies metamorphic rocks, and brittle deformation.
Upper delta plain setting	The part of a delta plain essentially unaffected by basinal processes. They do not differ substantially from alluvial environments except that areas of swamp, marsh and lakes are usually more widespread and channels may bifurcate downstream
Upper mantle setting	That part of the mantle which lies above a depth of about 660 km and has a density of 3.4 g/cm3 to 4.0 g/cm3 with increasing depth. Similarly, P-wave velocity increases from about 8 to 11 km/sec with depth and S wave velocity increases from about 4.5 to 6 km/sec with depth. It is presumed to be peridotitic in composition. It includes the subcrustal lithosphere the asthenosphere and the transition zone;
Upper oceanic crustal setting	Oceanic crustal setting dominated by extrusive rocks, abyssal oceanic sediment, with increasing mafic intrusive rock in lower part.
Volcanic arc setting	A generally curvillinear belt of volcanoes above a subduction zone.
Wetland setting	Setting characterized by gentle surface slope, and at least intermittent presence of standing water, which may be fresh, brackish, or saline. Wetland may be terrestrial setting or shoreline setting.

EventProcessTerm

Code list
(CGI_Term, Class: GeologicEvent, Attribute: eventProcess)

Term	Definition
accretion	The addition of material to a continent. Typically involves convergent or transform motion.
alteration	General term for any change in the mineralogical or chemical composition of a rock. Typically related to interaction with hydrous fluids.
biological precipitation	the deposition of minerals from solution by the agency of organisms
biological weathering	breakdown of rocks by biological agents, e.g. the penetrating and expanding force of roots, the presence of moss and lichen causing humic acids to be retained in contact with rock, and the work of animals (worms, moles, rabbits) in modifying surface soil
bolide impact	the impact of an extraterrestrial body on the surface of the earth
chemical precipitation	The deposition of mineral matter by precipitation from solution or as a result of chemical reactions. May be sedimentary or hydrothermal.
chemical weathering	The process of weathering by which chemical reactions (hydrolysis, hydration, oxidation, carbonation, ion exchange, and solution) transform rocks and minerals into new chemical combinations that are stable under conditions prevailing at or near the Earth's surface; e.g. the alteration of orthoclase to kaolinite.
cometary impact	the impact of a comet on the surface of the earth
contact metamorphism	Metamorphism taking place in rocks at or near their contact with a genetically related body of igneous rock
continental breakup	Fragmentation of a continental plate into two or more smaller plates; may involve rifting or strike slip faulting.
continental collision	The amalgamation of two continental plates or blocks along a convergent margin.
debris flow deposition	Laminar high-concentration, generally cohesionless deposition process. Flow types included liquefied flow, fluidized flow, grain flow, traction carpet or modified grain flow.
deep water oxygen depletion	Process of removal of oxygen from from the deep part of a body of water.
deformation	Movement of rock bodies by displacement on fault or shear zones, or change in shape of a body of Earth material.
deformation twinning	Deformation of a crystal by gliding to produce crystallographic twinning.
deposition	Accumulation of material; the constructive process of accumulation of sedimentary particles, chemical precipitation of mineral matter from solution, or the accumulation of organic material on the death of plants and animals.
deposition from moving fluid	Deposition of sediment from moving water or air, in which the sediment is transported by entrainment in the moving fluid. Constrast with debris flow or turbidity current deposition in which movement of fluid/sediment mixture is due to incorporation of sediment in fluid.
diagenetic process	Any chemical, physical, or biological process that affects a sedimentary EarthMaterial after initial deposition, and during or after lithification, exclusive of weathering and metamorphism. [adapt. Jackson, 1997] Example processes include compaction, cementation, authigenesis, replacement, leaching, hydration, and bacterial action. Includes processes that are normal in the surficial or outer part of the earth's crust [Jackson, 1997]. Changes in a deeply buried sedimentary rock may be continuous from diagenesis into recrystallization to form a metamorphic rock. Robertson [1999] defines the boundary between diagenesis and metamorphism in sedimentary rocks as follows: "the boundary between diagenesis and metamorphism is somewhat arbitrary and strongly dependent on the rock types involved. For example changes take place in organic materials at lower temperatures than in rocks dominated by silicate minerals. In mudrocks, a white mica (illite) crystallinity value of less than 0.42D.2U obtained by X-ray diffraction analysis, is used to define the onset of metamorphism (Kisch, 1991). In this scheme, the first appearance of glaucophane, lawsonite, paragonite, prehnite, pumpellyite or stilpnomelane is taken to indicate the lower limit of metamorphism (Frey and Kisch, 1987; Bucher and Frey, 1994; Frey and Robinson, 1998). Most

Term	Definition
	workers agree that such mineral growth starts at 150 ± 50° C in silicate rocks. Many rock types may show no change in mineralogy under these conditions and hence the recognition of the onset of metamorphism will vary with bulk composition."
diffusion creep	Grain-scale, ductile deformation accomplished by the motion of atoms through crystals, along grain boundaries, and through pore fluids.
dislocation metamorphism	Metamorphism concentrated along narrow belts of shearing or crushing without an appreciable rise in temperature
dissolution	The process of dissolving into a homogenous solution, as when an acidic solution dissolves limestone. In karst, refers to the process of dissolving rock to produce landforms, in contrast to solution, the chemical product of dissolution.
dissolution creep	Deformation by dissolution under the effects of differential stress and its transport to a new location by movement of fluid in the rock body.
ductile flow	deformation without apparent loss of continuity at the scale of observation.
effusive eruption	Eruptions characterized by low volatile content of the erupting magma relative to ambient pressure
erosion	The process of disaggregation of rock and displacement of the resultant particles (sediment) usually by the agents of currents such as, wind, water, or ice by downward or down-slope movement in response to gravity or by living organisms (in the case of bioerosion).
eruption	The ejection of volcanic materials (lava, pyroclasts, and volcanic gases) onto the Earth's surface, either from a central vent or from a fissure or group of fissures
excavation	removal of material, as in a mining operation
extinction	Process of disappearance of a species or higher taxon, so that it no longer exists anywhere or in the subsequent fossil record.
faulting	The process of fracturing, frictional slip, and displacement accumulation that produces a fault
folding	deformation in which planar surfaces become regularly curviplanar surfaces with definable limbs (zones of lower curvature) and hinges (zones of higher curvature).
fracturing	The formation of a surface of failure resulting from stress
frost shattering	Propagation of fractures due to expansion of freezing water in intergranular spaces and fractures in a rock body. Result is mechanical disintegration spliitting, or breakup of rock.
geologic process	process that effects the geologic record
geomagnetic process	process that results in change in Earth's magnetic field
grading	leveling of earth surface by rearrangement of prexisting material
haloclasty	propagation of fractures in rock due to crytallization of mineral salts (typically sodium chloride) from interstitial water, or volumetrick expansion of salts in capillaries, or hydration pressure of interstitial, trapped salts. Generally results in mechanical disintegration of the rock surface.
hawaiian eruption	Eruption in which great quantities of extremely fluid basaltic lava are poured out, mainly issuing in lava fountains from fissures on the flanks of a volcano. Explosive phenomena are rare, but much spatter and scoria are piled into cones and mounds along the vents. Characteristic of shield volcanoes
human activity	processes of human modification of the earth to produce geologic features
hydration	The process of absorption of water into the crystal structure of a mineral, thereby changing its volume and fracturing and loosening grains
hydrolysis	A decomposition reaction involving water. In geology, it commonly indicates reaction between silicate minerals and either pure water or aqueous solution. In such reactions, H
ice erosion	Erosion by corrasion or plucking by moving ice.
intrusion	The process of emplacement of magma in pre-existing rock
magmatic crystallisation	The process by which matter becomes crystalline, from a gaseous, fluid, or dispersed state
magmatic process	A process involving melted rock (magma).
magnetic field reversal	geomagnetic event
mass wasting	the dislodgement and downslope transport of soil and rock material under the

Term	Definition
	direct application of gravitational body stresses. In contrast to other erosion processes, the debris removed by mass wasting is not carried within, on, or under another medium. The mass properties of the material being transported depend on the interaction of the soil and rock particles and on the moisture content.
mass wasting deposition	A general term for the dislodgement and downslope transport of soil and rock material under the direct application of gravitational body stresses. In contrast to other erosion processes, the debris removed by mass wasting is not carried within, on, or under another medium. The mass properties of the material being transported depend on the interaction of the soil and rock particles and on the moisture content. Mass wasting includes slow displacements, such as creep and solifluction, and rapid movements such as rockfalls, rockslides, and cohesive debris flows (Jackson, 1997, p. 392). Includes both subaerial mass-wasting processes and subaqueous mass-wasting processes.
material transport and deposition	transport and heaping of material, as in a land fill, mine dump, dredging operations
mechanical deposition	process by which material that is being transported as particles by moving air, water, ice, or other fluid comes to rest and accumulates.
melting	change of state from a solid to a liquid
metamorphic process	Mineralogical, chemical, and structural adjustment of solid rocks to physical and chemical conditions that differ from the conditions under which the rocks in question originated, and are generally been imposed at depth, below the surface zones of weathering and cementation.
meteorite impact	the impact of a meteorite on the surface of the earth
microfracturing	Development of fractures within a single grain or cutting several grains.
obduction	The overthrusting of continental crust by oceanic crust or mantle rocks at a convergent plate boundary.
organic accumulation	sediment accumulation of biologically produced organic material, as in bog, coal swamps.
orogenic process	mountain building process.
oxidation	Chemical reaction that involve stripping of electrons from cations. Typicall reactions include converting sulfide minerals to oxide minerals, or increasing the oxidation state of cations in existing oxide minerals. The most commonly observed is the oxidation of Fe
partial melting	Process of melting involving only some of the mineral phases in a rock, to produce a mixture of melt and residual particles.
physical weathering	The process of weathering by which frost action, salt-crystal growth, absorption of water, and other physical processes break down a rock to fragments, involving no chemical change
plinian eruption	An explosive eruption in which a steady, turbulent stream of fragmented magma and magmatic gas is released at a high velocity from a vent. Large volumes of tephra and tall eruption columns are characteristic
polar wander	process of migration of the axis of the earth's dipole field relative to the rotation axis of the Earth.
pressure release weathering	propagation of fractures near the surface of solid rock due to expansion related to release of confining pressure when deeply buried rock is unroofed. Fractures typically propagate along surfaces close to and subparallel to the surface of the outcrop.
pyroclastic eruption	Eruption produced by the generation and rapid expansion of a gas phase that disrupts magma, surrounding wall rock or sediment
rifting	Extension of the crust to form one or more long, narrow graben of regional extent.
sea level change	process of mean sea level changing relative to some datum
sea level fall	process of mean sea level falling relative to some datum
sea level rise	process of mean sea level rising relative to some datum
sedimentary process	a phenomenon that changes the distribution or physical properties of sediment at or near the earth's surface
shearing	A deformation in which contiguous parts of a body are displaced relatively to each other in a direction parallel to a surface. The surface may be a discrete fault, or

Term	Definition
	the deformation may be a penetrative strain and the shear surface is a geometric abstraction.
speciation	process that results inappearance of new species
spreading	A process whereby new oceanic crust is formed by upwelling of magma at the center of mid-ocean ridges and by a moving-away of the new material from the site of upwelling at rates of one to ten centimeters per year.
strombolian eruption	Eruption characterized by jetting of clots or "fountains" of fluid, basaltic lava from a central crater
subduction	The process of one lithospheric plate descending beneath another
tectonic process	Processes related to the interaction between or deformation of rigid plates forming the crust of the Earth.
thermal shock weathering	propagation of fractures near the surface of solid rock due to expansion and contraction caused by temperature changes. Fractures typically propagate along surfaces close to and subparallel to the surface of the outcrop.
transform faulting	A strike-slip fault that links two other faults or two other plate boundaries (e.g. two segments of a mid-ocean ridge). Transform faults often exhibit characteristics that distinguish them from transcurrent faults: (1) For transform faults formed at the same time as the faults they link, slip on the transform fault has equal magnitude at all points along the transform; slip magnitude on the transform fault can exceed the length of the transform fault, and slip does not decrease to zero at the fault termini. (2) For transform faults linking two similar features, e.g. if two mid-ocean ridge segments linked by a transform have equal spreading rates, then the length of the transform does not change as slip accrues on it.
turbidity current deposition	Deposition from a turbulent, low concentration sediment-water mixture.
vulcanian eruption	Eruption characterized by the explosive ejection of fragments of new lava, commonly incandescent when they leave the vent but either solid or too viscous to assume any appreciable degree of rounding during their flight through the air. With these there are often breadcrust bombs or blocks, and generally large proportions of ash
water erosion	Erosion by clast impact or plucking by moving liquid water
weathering	The process or group of processes by which earth materials exposed to atmospheric agents at or near the Earth's surface are changed in color, texture, composition, firmness, or form, with little or no transport of the loosened or altered material. Processes typically include oxidation, hydration, and leaching of soluble constituents.
wind erosion	Erosion by clast impact or plucking by moving air (wind)

FaultTypeTerm

Code list

Term	Definition
Detachment fault	A regional-scale, large displacement, low-angle normal fault.
Dextral strike slip fault	Fault with right-lateral strike-parallel displacement component of slip vector more than 10 times the dip-parallel component of the slip vector at at least one location along the fault, and right-lateral displacement over more than half the mapped trace of the fault.
Extraction fault	A fault whose two sides have approached each other substantially in the direction perpendicular to the fault.
Fault	A discrete surface, or zone of discrete surfaces, with some thickness, separating two rock masses across which one mass has slid past the other and characterized by brittle deformation.
High angle reverse	Reverse fault that dips at least 45 degrees over more than half of its recognized extent, for which slip or separation is not explicitly specified.
High-angle fault	Fault that dips at least 45 degrees over more than half of its recognized extent, for which slip or separation is not explicitly specified.

Term	Definition
High-angle normal fault	Fault that dips at least 45 degrees over more than half of the recognized extent of the fault with the hanging wall displaced from a structurally higher position relative to footwall rocks.
Horizontal fault	Fault that dips less than 10 degrees over more than half the recognized extent of the fault.
Left normal fault	High angle fault with slip vector that has ratio of strike-parallel to dip-parallel displacement between 10 to 1 and 1 to 10 at at least one location along the mapped trace, with left-lateral strike-parallel component and normal dip-parallel component over at least half the mapped trace of the fault.
Left reverse fault	High angle fault with slip vector that has ratio of strike-parallel to dip-parallel displacement between 10 to 1 and 1 to 10 at at least one location along the mapped trace, with left-lateral strike-parallel component and reverse dip-parallel component over at least half the mapped trace of the fault.
Low angle fault	Fault that dips less than 45 degrees over more than half of the recognized extent of the fault.
Low-angle normal fault	Fault that dips less than 45 degrees over more than half of the recognized extent of the fault with the hanging wall displaced from a structurally higher position relative to footwall rocks.
Mixed extraction fault	An extraction fault with some displacement within the fault plane.
Normal fault	Fault with dip-parallel displacement component of slip vector more than 10 times the strike-parallel component of the slip vector over more than half recognized extent of the fault, and for which the fault dips consistently in the same direction, and for which the hanging wall has been displaced down relative to the footwall.
Oblique slip fault	Fault with slip vector that has ratio of strike-parallel to dip-parallel displacement between 10 to 1 and 1 to 10 at at least one location along the mapped trace of the fault.
Pure extraction fault	An extraction fault with no discernible displacement within the fault plane.
Reverse fault	Fault with dip-parallel displacement component of slip vector more than 10 times the strike-parallel component of the slip vector at at least one location along the mapped trace of the fault, and the fault dips consistently in the same direction with the hanging wall displaced up relative to the footwall over at least half the mapped trace of the fault.
Right normal fault	High angle fault with slip vector that has ratio of strike-parallel to dip-parallel displacement between 10 to 1 and 1 to 10 at at least one location along the mapped trace, with right-lateral strike-parallel component and normal dip-parallel component of slip over at least half the mapped trace of the fault
Right reverse fault	High angle fault with slip vector that has ratio of strike-parallel to dip-parallel displacement between 10 to 1 and 1 to 10 at at least one location along the mapped trace, with a right-lateral strike-parallel component and reverse dip-parallel component of slip over at least half the mapped trace of the fault.
Scissor fault	A fault on which there is increasing offset or separation along the strike from an initial point of no offset, with the opposite sense of offset in the opposite direction.
Sinistral strike slip fault	Fault with left-lateral strike-parallel displacement component of slip vector more than 10 times the dip-parallel component of the slip vector at at least one location along the fault, and left-lateral displacement over more than half the mapped trace of the fault.
Strike slip fault	Fault with strike-parallel displacement component of slip vector more than 10 times the dip-parallel component of the slip vector at at least one location along the mapped trace of the fault.
Thrust fault	Fault that dips less than 45 degrees over more than half of the recognized extent of the fault, with a hanging wall displaced from a structurally deeper position relative to footwall rocks.
Wrench fault	A strike slip fault in which the fault plane dips at least 45 degrees over more than half of the recognized extent of the fault.

FeatureObservationMethod

Code list
(CGI_Term, Class: GeologicFeature, Attribute: observationMethod)

Term	Definition
Borehole cuttings observation	Data based on interpretation of borehole cuttings
Borehole geophysical log measurements	Data based on interpretation of geophysical measurement obtained by borehole logging tools.
Data from single published description	Data are extracted from a publised description of the feature
Digital conversion from published source	Feature observation is based on published information, converted to a digital representation for database application
Direct observation	Feature observation is result of direct visual observation by a geologist
Drill core observation	Data collected through observation of a single drill core interval.
Drill core observation, estimated values	Values for properties are estimated by observer.
Drill core observation, measured values	Values for properties are measured using a device (compass, jacob staff, scintillometer, clinometer, ruler…)
Indirect method	Feature observation based on inference from proxy observation
Outcrop observation	Data collected in field through direct observation of a single outcrop. Observer defines scope of 'single outcrop'--may be one point location, or averaged over an extended but connected) area, e.g. a single polygon on a map. Direct observation may include observation using a remote camera (e.g. downhole viewer, submarine camera)
Outcrop observation, estimated values	Values for properties are estimated by observer.
Outcrop observation, measured values	Values for properties are measured using a device (compass, jacob staff, scintillometer, clinometer, ruler…)
Remotely sensed data	Geologic unit or structure characterized based on remotely sensed data.
Synthesis from multiple sources	Feature observation is based on a synthesis of other observations by some compiler. The compiler may be the same individual that made the source observations.
Synthesis of multiple outcrop observations	Data are the result of synthesis from multiple direct observations, posibly by more than one observer
Synthesis of multiple published descriptions	Data are the result of synthesis from multiple published descriptions

GeneticCategory

Code list
(CGI_Term, Class: CompoundMaterial, Attribute: geneticCategory)

Term	Definition
anthropogenic genesis	Formation predominantly by human activity.
biological sedimentary genesis	Formation predominantly by deposition of material produced by living organisms either as part of their body (e.g., exoskeleton, bone, pollen, wood) or through their activities (e.g., faecal pellets).
cataclastic genesis	Formation predominantly by brittle deformation, i.e. the formation and growth of fractures and frictional sliding along fracture surfaces.
chemical sedimentary genesis	Formation predominantly by direct chemical precipitation (e.g., evaporites, exhalative deposits).
clastic sedimentary genesis	Formation predominantly by accumulation of particles (clasts) derived by weathering, erosion, or fragmentation of pre-existing rock or produced by chemical or biologically-mediated precipitation.
composite process genesis	Formation in which more than one genetic process is dominant. This usually involves some combination of igneous, weathering, sedimentary, metamorphic, deformation or impact-related processes that better represents the origin of the

Term	Definition
	material
contact metamorphic genesis	Formation predominantly by metamorphism due to the effect of a magma body on the rocks it intrudes.
deformation genesis	Formation predominantly by strain-related processes resulting in changes of shape of a rock body, including folding, faulting, shearing, or fabric development; deformation may be either brittle or ductile. Local deformation metamorphic genesis related to a particular fault or shear zone is categorized as 'Dislocation metamorphic genesis'
diagenetic genesis	Formation predominantly by chemical and physical changes subsequent to deposition of sediment, during and after lithification that occur under temperature and pressure conditions too low to be considered metamorphic.
dislocation metamorphic genesis	Formation predominantly by metamorphism of local extent associated with fault zones or shear zones. 'Dislocation metamorphic genesis' is 'Deformation genesis' of local extent, explicitly associated with a particular fault or shear zone.
ductile deformation genesis	Formation predominantly by deformation without loss of material continuity at the scale of observation.
hypabyssal intrusive genesis	Formed by crystallisation close to the Earth's surface, characterized by more rapid cooling than plutonic setting to produce generally fine-grained intrusive igneous rock, commonly associated with co-magmatic volcanic rocks.
igneous extrusive genesis	Formation predominantly by crystallisation of magma at or immediately adjacent to Earth's surface.
igneous genesis	Formation predominantly by crystallisation from magma
igneous intrusive genesis	Formation predominantly by crystallisation of magma within the Earth.
igneous sedimentary genesis	Formation by a combination of igneous and sedimentary processes
impact genesis	Formation predominantly by metamorphism related to the passage of a shock wave through a body of material, typically the result of impact of a planetary body (impactor) on a planetary surface (target)
local metamorphic genesis	Formation predominantly by metamorphism that may be attributed to a localized cause, such as magmatic intrusion, faulting, metorite impact, combustion of naturally occuring substances (coal), or lightning.
metaigneous genesis	Formation by metamorphism of an igneous protolith
metamorphic genesis	Formation predominantly by closed-system changes in mineralogy, texture, or fabric of a rock in response to chemical and physical conditions that have been imposed below the surface zones of weathering and cementation (diagenesis), and that differ from the conditions under which the rocks in question originated. As defined here the changes in rock volume may include removal of some chemical constituents from the system (especially water and other volatile constituents). Note narrower use that Neuendorf et al. 2005; this vocabulary distinguishes metasomatism from metamorphism.
metamorphic metasomatic or hydrothermal genesis	Formation predominantly by changes in chemical, mineralogical, or structural properties of rocks in response to chemical and physical conditions that have been imposed below the surface zones of weathering and cementation (diagenesis), and that differ from the conditions under which the rocks in question originated.
metaplutonic genesis	Formation by metamorphism of a plutonic igneous protolith.
metasedimentary genesis	Formation by metamorphism of a sedimentary protolith.
metasomatic or hydrothermal genesis	Formation predominantly by open-system changes in chemical composition by reaction with an external source, typically involving chemical transport by a fluid medium flowing through the rock. Metasomatism typically involves introduction of chemical constituents into a rock volume.
metavolcanic genesis	Formation by metamorphism of an extrusive igneous protolith.
plutonic genesis	Formation predominantly by crystallisation of magma far enough below Earth surface that complete crystallization of magma bodies forms holocrystalline medium to coarse grained igneous rock, wall rocks generally do not include volcanic products related to the magma, and some contact metamorphism is

Term	Definition
	developed at intrusive contacts.
regional metamorphic genesis	Formation predominantly by metamorphic processes affecting a large rock volume, associated with large-scale tectonic processes.
sedimentary genesis	Formation predominantly by processes of erosion, mass wasting, transportation, deposition, precipitation and biogenic production that take place in Earth's hydrosphere and atmosphere.
subaerial extrusive genesis	Formation predominantly by crystallisation of magma either in the open air or immediately adjacent to the land surface.
subaqueous extrusive genesis	Formation predominantly by crystallisation of magma under water or ice.
volcaniclastic genesis	Formation by a combination of extrusive igneous activity and sedimentary transport and deposition.
weathering genesis	Formation predominantly by the physical, chemical or biological alteration of rock or sediment at or near the Earth surface; connotes involvement of processes related to the atmosphere (weather...).

GeoChronologicEraNameValue

Code list

Term	Definition
Aeronian	
Albian	
Anisian	
Aptian	
Aquitanian	
Archean	
Artinskian	
Asselian	
Bajocian	
Barremian	
Bartonian	
Bashkirian	
Bathonian	
Berriasian	
Burdigalian	
Calabrian	
Callovian	
Calymmian	
Calymmian 1 *	
Calymmian 2 *	
Calymmian 3 *	
Calymmian 4 *	
Cambrian	
Cambrian-Series 2	
Cambrian-Series 3	
Cambrian-Series 3-Stage 5	
Cambrian-Stage 10	
Cambrian-Stage 2	
Cambrian-Stage 3	
Cambrian-Stage 4	
Cambrian-Stage 9	
Campanian	
Capitanian	
Carboniferous	

Term	Definition
Carnian	
Cenomanian	
Cenozoic	
Changhsingian	
Chattian	
Cisuralian	
Coniacian	
Cretaceous	
Cryogenian	
Danian	
Dapingian	
Darriwilian	
Devonian	
Drumian	
Early/Lower Cretaceous	
Early/Lower Devonian	
Early/Lower Jurassic	
Early/Lower Ordovician	
Early/Lower Triassic	
Ectasian	
Ectasian 1 *	
Ectasian 2 *	
Ectasian 3 *	
Ectasian 4 *	
Ediacaran	
Eifelian	
Emsian	
Eoarchean	
Eocene	
Famennian	
Floian	
Fortunian	
Frasnian	
Furongian	
Gelasian	
Givetian	
Gorstian	
Guadalupian	
Guzhangian	
Gzhelian	
Hadean (informal)	
Hauterivian	
Hettangian	
Hirnantian	
Holocene	
Homerian	
Induan	
Ionian	
Jurassic	
Kasimovian	
Katian	
Kimmeridgian	
Kungurian	
Ladinian	
Langhian	
Late/Upper Cretaceous	

Term	Definition
Late/Upper Devonian	
Late/Upper Jurassic	
Late/Upper Ordovician	
Late/Upper Pennsylvanian	
Late/Upper Pleistocene	
Late/Upper Triassic	
Llandovery	
Lochkovian	
Lopingian	
Ludfordian	
Ludlow	
Lutetian	
Mesoarchean	
Mesoproterozoic	
Mesozoic	
Messinian	
Middle Devonian	
Middle Jurassic	
Middle Ordovician	
Middle Triassic	
Miocene	
Mississippian	
Moscovian	
Maastrichtian	
Neoarchean	
Neoarchean 1 *	
Neoarchean 2 *	
Neogene	
Neoproterozoic	
Norian	
Olenekian	
Oligocene	
Ordovician	
Orosirian	
Orosirian 1 *	
Orosirian 2 *	
Orosirian 3 *	
Orosirian 4 *	
Orosirian 5 *	
Orosirian 6 *	
Orosirian 7 *	
Oxfordian	
Paibian	
Paleoarchean	
Paleocene	
Paleogene	
Paleoproterozoic	
Paleozoic	
Pennsylvanian	
Permian	
Phanerozoic	
Piacenzian	
Pleistocene	
Pliensbachian	
Pliocene	

Term	Definition
Pragian	
Precambrian	
Priabonian	
Pridoli	
Proterozoic	
Quaternary	
Rhaetian	
Rhuddanian	
Rhyacian	
Roadian	
Rupelian	
Sakmarian	
Sandbian	
Santonian	
Selandian	
Serpukhovian	
Serravallian	
Sheinwoodian	
Siderian	
Siderian 1 *	
Siderian 2 *	
Silurian	
Sinemurian	
Statherian	
Statherian 1 *	
Statherian 2 *	
Statherian 3 *	
Statherian 4 *	
Stenian	
Stenian 1 *	
Stenian 2 *	
Telychian	
Terreneuvian	
Thanetian	
Tithonian	
Toarcian	
Tonian	
Tonian 1 *	
Tonian 2 *	
Tortonian	
Tournaisian	
Tremadocian	
Triassic	
Turonian	
Valanginian	
Visean	
Wenlock	
Wordian	
Wuchiapingian	
Ypresian	
Zanclean	
Aalenian	

GeochronologicEraRank

Enumeration

Term	Definition
Age	
Chron	
Eon	
Epoch	
Era	
Period	
Sub-Age	
Sub-Eon	
Sub-Epoch	
Sub-Era	
Sub-Period	

GeologicUnitComposition

Code list

Term	Definition
Acid	> 66 wt% SiO2
Alkalic/Alkaline	The chemical content of the alkalies (Na and K) is great enough for alkaline minerals to form.
Argillic	Greater than accessory amount (greater than 5 percent by volume) of clay is present
Basic	45-52 wt% SiO2
Calcsilicate	Material consists of greater than or equal to 50 percent calcsilicate or carbonate minerals and carbonate minerals less than or equal to calcsilicate minerals in mineral mode.
Carbonaceous	Material containing significant carbon or hydrocarbon mineral phases, including graphite, coal, oil, gas, lignite, peat.
Carbonate	Material consists of greater than 50 percent calcsilicate or carbonate minerals and carbonate minerals greater than calcsilicate minerals in mineral mode. Metacarbonate of NADMSC SLTTm (2004) terminology, adopted here for non-genetic use.
Chloritic	Greater than accessory amount (greater than 5 percent by volume) of chlorite group minerals are present
Dolomitic	Dolomite is present, carbonate minerals form less than 50 percent of rock.
Feldspathic	Sedimentary material contains significant feldspar mineral content
Felsic	Silica content ranges from about 55% to > 70%. Potassium feldspar makes up more than one-third of total feldspars; plagioclase (Na & Ca) feldspars are less than two-thirds of total feldspars. (Travis 1955)
Ferromagnesian	Material consists of greater than 40 percent dark ferromagnesian silicate minerals. Standard term defined by Bates and Jackson (1987) to mean 'containing iron and magnesium'. Subsumes mafic and ultramafic.
Ferruginous	Greater than accessory amount (greater than 5 percent by volume) of non-silicate iron minerals (hematite, magnetite, siderite...) are present. Rocks containing abundant iron-rich silicate minerals would use the 'Ferromagnesian' terms.
Impure calcsilicate or carbonate	Material consists of greater than 50 percent calcsilicate or carbonate minerals and relative proportion of calcsilicate and carbonate minerals is unknown or not specified.
Intermediate	Silica content ranges from about 55% to 65%. Plagioclase feldspars make up more than two-thirds of total feldspars. Na-rich plagioclase predominates over Ca-rich plagioclase.
Mafic	Material consists of greater than or equal to 40 percent and less than 90 percent ferromagnesian silicate minerals.
Metaluminous	Chemical composition term used for igneous rocks, denoting that content of

Term	Definition
	aluminum oxide is greater than sodium oxide plus potassium oxide, but aluminum oxide less than sum of Na, K and Ca oxide.
Micaceous	Greater than accessory amount (greater than 5 percent by volume) of mica group mineral are present
Oxide	Material predominantly composed of oxide minerals
Pelitic	Material for which the sum of modal quartz+feldspar+ mica + aluminous mineral is greater than or equal to 70 percent, and aluminous mineral + mica content is greater than or equal to 40 percent.
Peralkaline	Aluminum oxide (Al2O3) is less than sum of K and Na oxide.
Peraluminous	Aluminum oxide (Al2O3) greater than sum of Na, K and Ca oxide.
Quartz-feldspar-pelitic	Material for which the sum of modal quartz+feldspar+ mica + aluminous mineral is greater than or equal to 70 percent.
Quartzo-feldspathic	Material for which the sum of modal quartz+feldspar+ mica + aluminous mineral is greater than or equal to 70 percent, and quartz + feldspar (sensu Robertson, 1999) greater than 60 percent.
Quartzose	Material consists of greater than or equal to 75 percent quartz.
Semi-pelitic	Material for which the sum of modal quartz+feldspar+ mica + aluminous mineral is greater than or equal to 70 percent, and quartz+ feldspar less than 60 percent
Silicate	
Subalkalic/subalkaline	The chemical content of the alkalies (Na and K) is not great enough for alkaline minerals to form.
Subaluminous	Aluminum oxide within 10 percent of sum of Na and K oxide.
Sulphate	Material predominantly composed of sulphate minerals
Sulphide	Material predominantly composed of sulphide minerals
Ultrabasic	< 45 wt % SiO2
Ultramafic	Material consists of greater than 90 percent ferromagnesian silicate minerals..
Ultrapotasic	K2O/Na2O > 2, K2O > 3%, MgO > 3%, Foley et al 1987. The ultrapotassic rocks.

GeologicUnitExposureColour

Code list

Term	Definition
black	
brown	
brownish yellow	
dark brown	
dark gray	
dark grayish brown	
dark grayish green	
dark greenish gray	
dark greenish gray/dark bluish gray	
dark grey	
dark olive brown	
dark olive gray	
dark red	
dark reddish brown	
dark reddish gray	
dark reddish grey	
dark yellowish brown	
dusky red	
gray	
grayish brown	
grayish green	
greenish black	

Term	Definition
greenish black/bluish black	
greenish gray	
greenish gray/bluish gray	
light brown	
light brownish gray	
light gray	
light greenish gray	
light greenish gray/light bluish gray	
light olive brown	
light olive gray	
light red	
light reddish brown	
light reddish gray	
light yellowish brown	
olive	
olive brown	
olive gray	
olive yellow	
pale brown	
pale green	
pale olive	
pale red	
pale yellow	
pink	
pinkish gray	
pinkish white	
red	
reddish black	
reddish brown	
reddish gray	
reddish yellow	
strong brown	
very dark brown	
very dark gray	
very dark grayish brown	
very dark grey	
very dusky red	
very pale brown	
weak red	
white	
yellow	
yellowish brown	
yellowish red	

GeologicUnitMorphology

Code list
(CGI_Term, Class: GeologicUnit, Attribute: bodyMorphology)

Term	Definition
arch morphology	a raised elongate body, morphologically equivalent to upside down channel
arcuate sheet	sheet in which one of L or W is a curved arc

Term	Definition
basin shape	Geometric analog is convex down discoid, term generally connotes a kilometer-scale feature. Map view may be circular, elliptical, or irregular; characteristic feature is thickening from the edges towards the center. Typically used to describe a body of sedimentary rock deposited in a low area in the Earth's crust, in which case there is an implication that the top is (or was) a surface of deposition.
blanket shape	a thin, widespread body with width to thickness ratio greater than 1000 to 1 that covers an underlying substrate. A layer of known great lateral extent. Morphology equivalent to bed or layer, but implies that body forms the top of some unit, instead of occurring within a body.
blob	Body with smooth surface, broadly equant shape, irregular protuberances, no symmetry axes, and a boundary that can not be separated into sides.
block	Equant polygonal cylinder, L=W=H, definable edges separate bounding surfaces. Grades to tabular prism as one horizontal dimension becomes distinctly longer than the other, and tablet or polygonal cylinder as one vertical axis becomes distinctly shorter or longer than the horizontal axes.
boudin shape	Layer or bed of rock deformed into sausage-shaped segments (boudins), either separated or joined by pinched connections. Morphology generally defined in a profile view, third dimension is not denoted; use of term also implies that the body is not isolated, but is related to an original body elongate on some dimension that has been stretched and separated into separate bodies
bread loaf ellipsoid	Ellipsoid with L 10 times W or H
channel shape	a strongly elongate lens or ribbon with a convex downward lower surface, near planar upper surface. Morphology is equivalent to upside down arch.
circular cylinder	Elliptical cylinder that has circular symmetry about long axis; distinct side surfaces are not defined. Cross section is circular
circular profile	equant profile with arcuate boundary
column shape	Cylindrical body, equant cross section, long in direction normal to equant cross section. Morphology equivalent to pipe, without denotation of transport function.
cone segment	Body that is section of a cone formed by splitting the cone along a surface parallel to the cone axis, that interesect approximately along the axis.
cone shape	discus with one planar side, and circular symmetry on axis; geologic cones typically have height <(<) diameter
conical sheet	sheet that conforms to surface of a cone.
cupola	a large upward projection of the roof of an igneous intrusion into the country rock above. A possibly irregular dome like or columnar body rooted in a larger body.
cylinder	Body defined by translation of a generating plane figure with approximately equant cross section (circle, ellipsoid, polygon) along a straight axial line. H>=W=L. Axis is direction normal to generating plane figure, which forms parallel top and bottom bounding surface.
dart ellipsoid	Ellipsoid with L more than 50 times W or H
diapir	Broadly inverted tear drop morphology. Body of magmatic or mobile sedimentary material intruded into overlying rocks
dike	A generally sheet-like intrusive rock body that cuts across bedding or foliation in the host rock, or intrudes massive host rock.
disc	Cylinder with height less than diameter. L=W>H; edges separates side from top and bottom. Grades to oblate ellipsoid as edges lose definition.
discoid anulus	Cone with central part removed along cylindrical volume approximately along the cone axis
discus	Body with two sides that converge to define an edge that is circular in profile; edge separates definable top and bottom. L=W>H. Grades to oblate ellipsoid as edge separating sides loses definition, cone as one side becomes distinctly planar.
dome	Steep-sided disk-like body, for example and accumulation of high viscosity lava above and around a volcanic vent. A structure in which the top of the body dips gently away in all directions e.g. salt dome, extrusion dome
dome sheet	sheet in which L and W are curved arcs.
ductolith	Concordant intrusion, teardrop-shaped in cross section.
ellipsoid	Body that contains three orthogonal axes defining three surfaces of reflection

Term	Definition
	symmetry, profiles along the surfaces are elliptical. Boundary can not be separated into sides (no edges). Becomes cylinder or disc when bounding surface can be considered parallel to one of the axis. L>=W>=H
elliptical cylinder	Cylinder that has elliptical cross section; distinct side surfaces are not defined.
elliptical profile	Profile approximates an ellipse; ratio of long axis to short axis is greater than 1.4
elongate discus	discus for which the profile defined by the bounding edge is longer in one direction than other. L>W>>H
equant polygonal profile	equant profile with boundary that can be divided into distinct straight sides separated by higher curvature corners.
equant profile	profile for which the ratio of length of longest chord to shortest chord is less than 1.4.
ethmolith	discordant, funnel-shaped intrusion, tapers downward
fan	A cone segment, generally applied to surface morphology of sedimentary deposit with a gentle surface slope, radiating from a localized sediment source.
football ellipsoid	Ellipsoid with L 2 to 5 times W or H
geologic body	A 3 dimensional body defined based on geometric shape, with some geologic connotation or denotation.
graben shape	an elongate body bounded on both sides by normal faults that dip toward each other
hemispheroid	Section of a spheroid formed by removing everything on the smaller volume side of a surface that intersects the spheroid. Grades to cone as suface generator (line rotated about axis to generate volume above lower planar boundary) becomes straight.
irregular profile	profile does not conform to any of the regular geometries associated with other categories in the vocabulary.
laccolith	A tabular or lenticular igneous body whose long dimensions parallel layering in the host rock, and which as a convex-up roof and a known or assumed flat floor
layer shape	Body geometry characterized by generally thin character relative to the lateral extent of the body (on order of 1:100). Thin bodies of lesser extent are lenses. Connotes a non-intrusive body; equivalent intrusive body would be dike (or sill). Denotes that body is in a sequence of similar sheet-like bodies between other rock bodies
lens	A body bounded by converging surfaces (at least one of which is curved), thick in the middle and thinning out toward the edges, resembling a convex lens.
lenticular profile	profile with ratio of long axis length to short axis length greater than 5 with sides that taper to a point, shaped like the profile of an optical lense.
longitudinal section of cylinder	Body that is section of a circular or elliptical cylinder formed by a splitting the cylinder along a surface approximately parallel to its long axis. L>>W>H.
lopolith	a large, concordant, typically layered igneous intrusion whose floor is convex-down and whose roof may be convex-down or flat.
mound	Lense like body of rock, lateral extent less than 100m, generally flat at bottom, with stratigraphic pinch out of beds (onlap) along upper sides.
pancake ellipsoid	Ellipsoid with H on order of .01 of L or W
phacolith	concordant, lenticular intrusion, emplaced along a fold axis
pillow ellipsoid	Ellipsoid with H on order of 0.1 of L or W
pipe	
planar profile	shape is defined by intersection of body with some surface, generally either a cross section or map view
planar sheet	sheet in which L and W axes are straight lines
planar vein	vein with length and width significantly greater than its thickness, giving the vein a tabular form
pod	a small intrusion of elongate or lenticular form
polygonal cylinder	Cylinder in which the edges bounding side surfaces are parallel or subparallel to cylinder axis. Cross section is polygon. Length of axis may be called height or thickness, and is typically in the vertical direction (distinguishing polygonal cylinder from tabular prism and wedge).
polygonal profile	Profile for which the ratio of length of longest chord to shortest chord is greater

Term	Definition
	than 1.4.profile and a boundary that can be divided into distinct straight sides separated by higher curvature corners.
prism	Body of material that is long in one dimension, and thins rapidly in a perpendicular direction. A long narrow wedge-shaped body that has a width to thickness ratio greater than 5 to 1 but less than 50 to 1 (Krynine, 1948). Similar to wedge, but profile may be variable
ribbon	Body that is very thin relative to width and and length. Long axis may be curved. L>(>>)W>>>H. H is typically in vertical direction.
ring dike	an arcuate or subcircular dyke, generally associated with a volcanic centre.
rock body geometry irregular	Rock body geometry is irregular and can not be characterized using terminology.
rock body geometry not specified	Rock body geometry is not specified. Use in normative descriptions where any morphology is allowed.
rod	Cylinder with very long axis, generally circular or elliptical cross section (generating figure). H>>>W=L. Long axis may be in any orientation, and may be curved.
sheet	Body that is very thin relative to lateral extent, so thin that is considered to consist of two bounding surfaces joined at an edge. Aspect ratio is L=W>>>H. The geometry of the edge joining the surfaces is not specified in the definition. If the geometry of the edge comes into play in the definition, becomes ribbon, disc or tablet(?). Includes dike, vein, sill and bed-shaped geologic units.
sheet ellipsoid	Ellipsoid with one axis much smaller than others H on order of .001 of L or W
sigmoid sheet	sheet with 's' curvature of L or W direction
sigmoidal vein	vein curved so as to resemble the letter S in section
sill form	a tabular intrusive igneous body with long dimensions parallel to bedding or foliation of sedimentary or metamorphic host rock.
sphenolith	wedge-like intrusion, partly concordant, partly discordant.
spheroid	Ellipsoid with L, W, H all approximately equal
square profile	polygonal profile that approximates a square
tablet	Polygonal cylinder with height less than length or width, disc with edges separating side into multiple segments.
tabular prism	Body defined by pairs of parallel, approximately planar surfaces separated by definable edges. Grades to ellipsoid as edges lose definition, to block as axial ratios approach 1, to polygonal cylinder as L approaches W. L>>W>H. H is in vertical direction, L is horizontal.
tear drop	Body bounded by hemispheroid on one side, cone on other, with circular symmetry around cone axis
three dimensional body	any three dimensional body
trough shape	shape of a body of sedimentary rock deposited in an elongate depression filled with sediment. large size distinguishes from channel
vein-shape	a tabular or sheetlike epigenetic mineral filling of a fault or fracture
wedge	Body defined by translation of trangle with W >> H along a horizontal axis. A polygonal cylinder with wedge-like triangular generating surface and horizontal axis. Body changes thickness (H) in W direction, approaching 0 thickness on one side. L>>W>H.

GeologicUnitOutcropCharacter

Code list

Term	Definition
bouldery	Rocks of this unit occur as boulders in outcrop
cliff-forming	Outcrops with rocks of this unit form cliffs
fine-grained	Rocks of this unit occur as unconsolidated fine-grained material in outcrop
gravelly	Rocks of this unit occur as gravel in outcrop
ledge-forming	Rocks of this unit form ledges in outcrop. The ledges can occur as steps or be

Term	Definition
	separated by recesses
poorly exposed	Rocks of this unit are generally poorly exposed
ridge-forming	Outcrops with rocks of this unit is seen as ridges. Ridge-formed outcrops can for example be formed where the softer host rock along a dike has been removed.
rounded hills and knobs	Rocks of this unit occur as rounded hills and knobs. The shapes are typically formed through spheroidal weathering
slope-forming	Outcrops with rocks of this unit is seen on slopes

GeologicUnitTypeTerm

Code list
(CGI_Term, Class: GeologicUnit, Attribute: geologicUnitType)

Term	Definition
Allostratigraphic Unit	Geologic unit defined by bounding surfaces. Not necessarily stratified. Donovon (2004, IUGS abstract Florence) makes good case for use of a noncommittal term for the bounding surface. “While there may be no agreement that a given stratal boundary is a discontinuity, there is consensus that all the identified boundaries are stratal surfaces.” Includes: 1. Unconformity bounded units (Salvador 1994), defined by bounding stratigraphic discontinuities ('significant unconformities'; unconformity is defined as surface of erosion in Salvador 1994). 2. Sequence stratigraphic unit, an allostratigraphic unit that is used to interpret the depositional origin of sedimentary strata and assumes, though this is not always stated, an implicit connection to base level change. It does this by establishing how the sequence of strata accumulated in order in the sedimentary section over a subdividing framework of surfaces.
Alteration Unit	Geologic unit defined by alteration process.
Artificial Ground	Geologic unit defined by genesis involving direct human action to deposit or modify material.
Biostratigraphic Unit	Geologic unit defined based on fossil content. Five kinds of biozones are recognized by the revised NACSN (Lenz et al., 2000, Note 64, a recommended complete replacement of Articles 48 through 54 of the North American Stratigraphic Code (NACSN, 1983) accepted for publication 2000.): range biozone, interval biozone, lineage biozone, assemblage biozone, and abundance biozone. These represent different approaches to defining and recognizing biozones.
Chronostratigraphic Unit	Geologic unit that includes all rocks formed during a specific interval of geologic time
Deformation Unit	Lithotectonic unit defined by deformation style or characteristic geologic structure observable in outcrop.
Excavation Unit	Geologic unit defined by human-made genesis involving excavation. Not necessarily defined by landform (a hole...), as they could have been subsequently filled/landscaped etc. If the excavation is filled becomes an excavation with artificial ground wholly or partly superimposed on it. This sort of thing can become quite important in urban geology where an excavation can be filled and landscaped.
Geologic Unit	Type of geologic unit is unknown, unspecified, irrelevant, or some type not included in the vocabulary. Type makes no implication for required properties or cardinalities. This is the root concept for the type hierarchy.
Geomorphologic Unit	Geologic unit defined by surface landform, e.g. hummocky moraine
Geophysical Unit	Geologic unit defined by its geophysical characteristics. Denotes that the properties used to define the unit are measured by intrumental techniques, not directly observable by humans, e.g. density, magnetic susceptibility, magnetization, electrical conductivity.
Lithodemic Unit	Lithostratigraphic unit that lacks stratification
Lithogenetic Unit	Geologic unit defined by genesis. The genesis is manifested by material properties, but the material is not the defining property. Example-- alluvial

Term	Definition
	deposits, glacial deposits.
Lithologic Unit	Geologic unit defined by lithology independent of relationships to other units. Denotes a 'kind' of rock body characterized by lithology, e.g. basaltic rocks.
Lithostratigraphic Unit	Geologic unit defined on the basis of observable and distinctive lithologic properties or combination of lithologic properties and stratigraphic relationships. Denotes a particular body of rock.
Lithotectonic Unit	Geologic unit defined defined on basis of structural or deformation features, mutual relations, origin or historical evolution. Contained material may be igneous, sedimentary, or metamorphic.
Magnetostratigraphic Unit	Geologic unit defined by magnetic characteristics.
Mass Movement Unit	Geologic unit produced by gravity driven, down-slope displacemnt of material, and characterized by the type of movement giving rise to the deposit, and by how the individual movement types present in the deposit are related in time and space.
Pedoderm	Geologic unit defined based on soil development and character. Pedoderm is not a surface classification unit because soil classification requires knowledge of the soil profile, which always extends some distance beneath the surface.
Pedostratigraphic Unit	Geologic unit that represents a single pedologic horizon in a sequence of strata (consolidated or non-consolidated). The presence of an overlying geologic unit is required, but locally the soil horizon may be at the Earth surface (in which case is may be coincident with a Pedoderm). See discussion at https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/PedostratigraphicUnit
Polarity Chronostratigraphic Unit	Geologic unit defined by primary magnetic-polarity record imposed whien the rock was deposited or crystallized during a specific interval of geolgoic time. Kind of chronostratigraphic unit and kind of geophysical unit.

GeophPropertyTypeValue

Code list

Term	Definition
density	density (mass per volume)
gravityBouguerAnomaly	Bouguer anomaly
gravityFreeAirAnomaly	Bouguer anomaly
resistivity	Electric resistivity
salinity	Electric resistivity
seismicReflectivity	Seismic reflectivity
seismicVelocity	Electric resistivity
totalMagneticField	Magnitude of the total magnetic field

LinearDirectedCode

Code list

Term	Definition
directed	Indicates that the linear orientation is directed
directed down	Indicates that the linear orientation is directed below the horizon
directed up	Indicates that the linear orientation is directed above the horizon

LithologyTerm

Code list

Term	Definition

Term	Definition
basaltic rock	
breccia, angular rock fragments	
clay	
claystone	
coal	
dark igneous rocks	
gabbroic rock	
gneiss	
granitic rock	
gypsum, anhydrite	
limestone, chalk	
marble	
marl or peat	
material formed by weathering	
other igneous rock	
other metamorphic rock	
other plutonic rock	
other sedimentary rock	
other volcanic rock	
rhyolithic rock	
rocks in fault or crush zones	
salt	
sand	
sandstone	
schist, slate	
till	
tuffite	
volcanic blocks or ash	

MovementSenseTerm

Code list

Term	Definition
detachment	A regional-scale low-angle normal fault.
dextral	Right-lateral separation sense; in plan view, the side opposite the observer appears displaced to the right.
generic decollement	A large-displacement (kilometers or tens of kilometers) shallowly dipping to subhorizontal fault or shear zone.
no movement sense	The fault-parallel displacement is effectively zero, as in an extraction fault.
normal	The hanging wall appears to have moved down relative to the footwall; dip of fault usually 45-90 degrees.
normal dextral	The movement sense includes both normal and dextral components.
normal sinistral	The movement sense includes both normal and sinistral components.
reverse	The hanging wall appears to have moved down relative to the footwall; dip of fault usually greater than 45 degrees.
reverse dextral	The movement sense includes both reverse and dextral components.
reverse sinistral	The movement sense includes both reverse and sinistral components.
sinistral	Left-lateral separation sense; in plan view, the side opposite the observer appears displaced to the left.
thrust	Reverse fault with dip typically less than 45 degrees; horizontal compression, rather than vertical displacement is characteristic.
thrust decollement	A regional-scale low-angle thrust fault.

MovementTypeTerm

Code list

Term	Definition
dip separation sense	A fault along which there is some separation parallel to the dip of the fault.
dip slip	The net slip of the fault lies in the dip direction of the fault.
extraction	A fault whose two sides have approached each other substantially in the direction perpendicular to the fault.
horizontal	The fault is horizontal.
mixed extraction	An extraction fault with some displacement within the fault plane.
oblique slip	The net slip of the fault lies between the strike and dip directions of the fault; the slip vector rakes between 10 and 80 degrees in the plane of the fault.
pure extraction	An extraction fault with no discernible displacement within the fault plane.
scissor	A fault on which there is increasing offset or separation along the strike from an initial point of no offset, with reverse offset in the opposite direction.
strike separation sense	A fault along which there is some separation parallel to the strike of the fault.
strike slip	The net slip of the fault (slip vector) is parallel to the strike of the fault.
transcurrent	A large scale strike-slip fault in which the fault surface is steeply inclined.
transform	A variety of strike-slip fault along which the displacement suddenly stops or changes form; typically associated with mid-ocean ridges.
transpressional	A fault along which strike-slip deformation is accompanied by a component of shortening transverse to the fault.
transtensional	A fault along which strike-slip deformation is accompanied by a component of extension transverse to the fault.
wrench	A strike slip fault in which the faut plane is more or less vertical.

NaturalGeomorphologicFeatureTypeTerm

Code list

Term	Definition
`a`a lava flow	A type of basaltic lava flow dominated by `a`a lava and a characteristically rough, jagged, clinkery surface.
Alas	A type of thermokarst depression with steep sides and a flat, grass-covered floor, found in thermokarst terrain, produced by thawing of extensive areas of very thick and exceedingly ice-rich permafrost.
Alluvial cone	A semi-conical type of alluvial fan with very steep slopes; it is higher, narrower, and steeper (e.g., > 40% slopes) than a fan, and composed of coarser, and thicker layers of material deposited by a combination of alluvial episodes and to a much lesser degree, landslides (e.g., debris flow). Coarsest materials tend to concentrate at the cone apex.
Alluvial fan	A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes, shaped like an open fan or a segment of a cone, deposited by a stream (best expressed in semiarid regions) at the place where it issues from a narrow mountain or upland valley; or where a tributary stream is near or at its junction with the main stream. It is steepest near its apex which points upstream and slopes gently and convexly outward (downstream) with a gradual decrease in gradient.
Alluvial flat	(a) (colloquial: western U.S.A.) A nearly level, graded, alluvial surface in bolsons and semibolsons that lacks distinct channels, terraces, or flood plain levels. (b) (not referred) A general term for a small flood plain bordering a river, on which alluvium is deposited during floods.
Alluvial plain	(a) A large assemblage of fluvial landforms (braided streams, terraces, etc.,) that form low gradient, regional ramps along the flanks of mountains and extend great distances from their sources. (b) (not recommended, use flood plain.) A general,

Term	Definition
	informal term for a broad flood plain or a low-gradient delta.
Alluvial plain remnant	An erosional remnant of an alluvial plain which retains the surface form and alluvial deposits of its origin but was not emplaced by, and commonly does not grade to a present-day stream or drainage network.
Alluvial terrace	(not preferred) refer to stream terrace.
Alpine glacier	a) Any glacier in a mountain range except an ice cap or ice sheet. It usually originates in a cirque and may flow down into a valley previously carved by a stream. Compare – continental glacier. GG b) (not preferred – refer to U-shaped valley): (relict) - landforms or sediments formed, modified or deposited by a glacier in or on mountains or high hills that has since melted away.
Annular drainage pattern	A drainage pattern in which subsequent streams follow a roughly circular or concentric path along a belt of weak rocks, resembling in plan view, a ring-like pattern where the bedrock joints or fracturing control the parallel tributaries. It is best displayed in streams draining a maturely dissected granitic or sedimentary structural dome or basin where erosion has exposed rimming sedimentary strata of greatly varying degrees of hardness, as in the Red Valley which nearly encircles the domal structure of the Black Hills.
Area with chemical weathering	An area subjecto to a process of chemical weathering
Arete	A narrow, jagged mountain crest, often above the snowline, sculptured by alpine glaciers and formed by backward erosion of adjoining cirque walls.
Arroyo	(colloquial: southwest U.S.A.) The channel of a flat-floored, ephemeral stream, commonly with very steep to vertical banks cut in unconsolidated material; sometimes called a wash. It is usually dry but can be transformed into a temporary watercourse or short-lived torrent after heavy rain within the watershed.
Ash field	A more or less well-defined area that is covered by volcanic ash
Ash flow	(not preferred – see pyroclastic flow, pyroclastic surge) A highly heated mixture of volcanic gases and ash, traveling down the flank of a volcano or along the surface of the ground; produced by the explosive disintegration of viscous lava in a volcanic crater, or by the explosive emission of gas-charged ash from a fissure or group of fissures. The solid materials contained in a typical ash flow are generally unsorted and ordinarily include volcanic dust, pumice, scoria, and blocks in addition to ash. (Also called a pyroclastic flow.)
Atoll	A coral reef appearing in plan view as roughly circular, and surmounted by a chain of closely spaced, low coral islets that encircle or nearly encircle a shallow lagoon in which there is no land or islands of noncoral origin; the reef is surrounded by open sea.
Avalanche chute	The central, channel-like corridor, scar, or depression along which an avalanche has moved. An eroded surface marked by pits, scratches, and grooves.
Avalanche track	(not recommended as a landform term - use avalanche chute). The path formed by an avalanche. It may take the form of an open path in a forest, with bent and broken trees, or an eroded surface marked by pits, scratches, and grooves.
Back-barrier beach	A narrow, elongate, intertidal, sloping landform that is generally parallel with the shoreline located on the lagoon or estuary side of the barrier island, or spit.
Back-barrier flat	A subaerial, gently sloping landform on the lagoon side of the barrier beach ridge composed predominantly of sand washed over or through the beach ridge during tidal surges; a portion of a barrier flat.
Backshore	The upper or inner, usually dry, zone of the shore or beach, lying between the high-water line of mean spring tides and the upper limit of shore-zone processes; it is acted upon by waves or covered by water only during exceptionally severe storms or unusually high tides. It is essentially horizontal or slopes gently landward, and is divided from the foreshore by the crest of the most seaward berm.
Backslope	The hillslope profile position that forms the steepest and generally linear, middle portion of the slope. In profile, backslopes are commonly bounded by a convex shoulder above and a concave footslope below. They may or may not include cliff segments (i.e. free faces). Backslopes are commonly erosional forms produced by mass movement, colluvial action, and running water.

Term	Definition
Backswamp	A flood-plain landform. Extensive, marshy or swampy, depressed areas of flood plains between natural levees and valley sides or terraces.
Badlands	A landscape which is intricately dissected and characterized by a very fine drainage network with high drainage densities and short, steep slopes with narrow interfluves. Badlands develop on surfaces with little or no vegetative cover, overlying unconsolidated or poorly cemented materials (clays, silts, or in some cases sandstones) sometimes with soluble minerals such as gypsum or halite.
Bajada	A broad, gently inclined, alluvial piedmont slope extending from the base of a mountain range out into a basin and formed by the lateral coalescence of a series of alluvial fans. Typically it has a broadly undulating transverse profile, parallel to the mountain front, resulting from the convexities of component fans. The term is generally restricted to constructional slopes of intermontane basins. Synonym - coalescent fan piedmont.
Ballena	(colloquial: western U.S.A.) A fan remnant having a distinctively-rounded surface of fan alluvium. The ballena's broadly-rounded shoulders meet from either side to form a narrow summit and merge smoothly with concave side slopes and then concave, short pediments which form smoothly-rounded drainageways between adjacent ballenas. A partial ballena is a fan remnant large enough to retain some relict fan surface on a remnant summit.
Ballon	(colloquial: western U.S.A.) A rounded, dome-shaped hill, formed either by erosion or uplift.
Bank-attached bar	In braided streams, diagonal bars attached to either bank of a curved reach.
Bar	[streams] A general term for a ridge-like accumulation of sand, gravel, or other alluvial material formed in the channel, along the banks, or at the mouth of a stream where a decrease in velocity induces deposition; e.g. a channel bar or a meander bar. [coast] - A generic term for any of various elongate offshore ridges, banks, or mounds of sand, gravel, or other unconsolidated material submerged at least at high tide, and built up by the action of waves or currents, especially at the mouth of a river or estuary, or at a slight distance offshore from the beach.
Bar and channel topography	A local-scale topographic pattern of recurring, small, sinuous or arcuate ridges separated by shallow troughs irregularly spaced across low-relief flood plains(slopes generally 2 –6 %); the effect is one of a subdued, sinuously undulating surface that is common on active, meandering flood plains. Micro-elevational differences between bars and channels generally range from <0.5 to 2 m and are largely controlled by the competency of the stream. The ridge-like bars often consist of somewhat coarser sediments compared to the finer textured sediments of the micro-low troughs.
Barchan dune	A crescent-shaped dune with tips extending leeward (downwind), making this side concave and the windward (upwind) side convex. Barchan dunes tend to be arranged in chains extending in the dominant wind direction.
Barrier beach	A narrow, elongate, coarse-textured, intertidal, sloping landform that is generally parallel with the beach ridge component of a barrier island or spit and adjacent to the ocean.
Barrier cove	A subaqueous area adjacent to a barrier island or submerged barrier beach that forms a minor embayment or cove within the larger basin.
Barrier flat	A relatively flat, low-lying area, commonly including pools of water, separating the exposed or seaward edge of a barrier beach or barrier island from the lagoon behind it. An assemblage of both deflation flats left behind migrating dunes and /or storm washover sediments; may be either barren or vegetated.
Barrier island	A long, narrow, sandy island, that is above high tide and parallel to the shore that commonly has dunes, vegetated zones, and swampy or marshy terrains extending lagoonward from the beach.
Basin	(a) Drainage basin; (b) A low area in the Earth's crust, of tectonic origin, in which sediments have accumulated. GG (c) (colloquial: western USA) A general term for the nearly level to gently sloping, bottom surface of an intermontane basin (bolson). Landforms include playas, broad alluvial flats containing ephemeral drainageways, and relict alluvial and lacustrine surfaces that rarely, if ever, are subject to flooding. Where through-drainage systems are well developed, flood

Term	Definition
	plains are dominant and lake plains are absent or of limited extent. Basin floors grade mountainward to distal parts of piedmont slopes.
Basin floor	A general term for the nearly level, lower-most part of intermontane basins (i.e. bolsons, semibolsons). The floor includes all of the alluvial, eolian, and erosional landforms below the piedmont slope.
Basin-floor remnant	(colloquial: western U.S.A.) A relatively flat, erosional remnant of any former landform of a basin floor that has been dissected following the incision of an axial stream.
Bay	a) A wide, curving open indentation, recess, or arm of a sea (e.g. Chesapeake Bay) or lake (e.g. Green Bay, WI) into the land or between two capes or headlands, larger than a cove, and usually smaller than, but of the same general character as, a gulf. b) A large tract of water that penetrates into the land and around which the land forms a broad curve. By international agreement a bay is a water body having a baymouth that is less than 24 nautical miles wide and an area that is equal to or greater than the area of a semicircle whose diameter is equal to the width of the bay mouth.
Bay bottom	The nearly level or slightly undulating central portion of a submerged, low-energy, depositional estuarine embayment characterized by relatively deep water (1.0 to >2.5 m).
Bayou	A term applied to many local water features in the lower Mississippi River basin and in the Gulf Coast region of the U.S. Its general meaning is a creek or secondary watercourse that is tributary to another body of water; especially a sluggish and stagnant stream that follows a winding course through alluvial lowlands, coastal swamps or river deltas.
Beach	(a) A gently sloping zone of unconsolidated material, typically with a slightly concave profile, extending landward from the low-water line to the place where there is a definite change in material or physiographic form (such as a cliff) or to the line of permanent vegetation (usually the effective limit of the highest storm waves); a shore of a body of water, formed and washed by waves or tides, usually covered by sand or gravel; (b) the relatively thick and temporary accumulation of loose water-borne material usually well-sorted sand and pebbles) accompanied by mud, cobbles, boulders, and smoothed rock and shell fragments, that is in active transit along, or deposited on, the shore zone between the limits of low water and high water.
Beach plain	A continuous and level or undulating area formed by closely spaced successive embankments of wave-deposited beach material added more or less uniformly to a prograding shoreline, such as to a growing compound spit or to a cuspate foreland.
Beach ridge	A low, essentially continuous mound of beach or beach-and-dune material heaped up by the action of waves and currents on the backshore of a beach, beyond the present limit of storm waves or the reach of ordinary tides, and occurring singly or as one of a series of approximately parallel deposits. The ridges are roughly parallel to the shoreline and represent successive positions of an advancing shoreline.
Beach terrace	A landform that consists of a wave-cut scarp and wave-built terrace of well-sorted sand and gravel of marine and lacustrine origin.
Bell	A cone-shaped nodule or concretion in the roof of a coal seam, which may fall without warning.
Bell hole	(a) A cavity in the roof of a coal seam, produced by the falling of a bell. (b) A vertical dissolutional cylinder developed in a cave roof; mainly reported from the humid tropics.
Berm	A low, impermanent, nearly horizontal or landward-sloping shelf, ledge, or narrow terrace on the backshore of a beach, formed of material thrown up and deposited by storm waves; it is generally bounded on one side or the other by a beach ridge or beach scarp. Some beaches have no berms, others have one or several.
Beveled base	The lower portion of a canyon wall or escarpment marked by a sharp reduction in slope gradient from the precipitous cliff above, and characteristically composed of thinly mantled colluvium (e.g. < 1 m) and / or carapaced with a thin surficial mantle

Term	Definition
	of large rock fragments from above, which overly residuum of less resistant rock (e.g., shale) whose thin strata intermittently outcrop at the surface; a zone of erosion and transport common in the canyonlands of the semi-arid, southwestern USA.
Blind valley	A valley, commonly in karst, that ends abruptly downstream at the point at which its stream disappears underground.
Block field	A thin accumulation of stone blocks, typically angular, with only coarse fragments in the upper part, over solid or weathered bedrock, colluvium, or alluvium, without a cliff or ledge above as an apparent source. Block fields occur on high mountain slopes above tree-line, or in polar or paleo-periglacial regions; they are most extensive along slopes parallel to the contour; and they generally occur on slopes of less than 5%. Synonym - felsenmeer.
Block glide	The process, associated sediments (block glide deposit) or resultant landform characterized by a slow type of slide, in which largely intact units (blocks) of rock or soil slide downslope along a relatively planar surface, such as a bedding plane, without any significant distortion of the original mass; a type of translational rock slide.
Block lava flow	A lava flow dominated by block lava.
Block stream	An accumulation of boulders or angular blocks, with no fine sizes in the upper part, overlying solid or weathered bedrock, colluvium, or alluvium, and lying below a cliff or ledge from which coarse fragments originate. Block streams usually occur at the heads of ravines as narrow bodies that are more extensive downslope than along the slope. They may exist on any slope angle, but ordinarily not steeper than 90 percent slope (approx. 40 degrees).
Blowout	A saucer-, cup-, or trough-shaped depression formed by wind erosion on a preexisting dune or other sand deposit, especially in an area of shifting sand, loose soil, or where protective vegetation is disturbed or destroyed; the adjoining accumulation of sand derived from the depression, where recognizable, is commonly included. Commonly small, some blowouts may be large (kilometers in diameter).
Bluff	(a) A high bank or bold headland, with a broad, precipitous, sometimes rounded cliff face overlooking a plain or body of water, especially on the outside of a stream meander; ex. a river bluff. (b) (not preferred) use cliff. Any cliff with a steep, broad face.
Bog	Waterlogged, spongy ground, consisting primarily of mosses, containing acidic, decaying vegetation such as sphagnum, sedges, and heaths that may develop into peat.
Bolson	(colloquial: western USA.) A term applied to an internally drained (closed) intermontane basin in arid regions where drainages from adjacent mountains converge toward a central depression. Bolsons are often tectonically formed depressions. A bolson can include alluvial flat, alluvial plain, beach plain, barrier beach, lake plain, sand sheet, dune, and playa landforms. The piedmont slope above a bolson includes erosional (pediments) and older depositional surfaces (fans) that adjoin the mountain front. A semi-bolson is an externally drained (open) bolson. Synonym - intermontane basin.
Bomb	A pyroclast ejected while viscous and shaped while in flight. It is larger than 64 mm in diameter, and may be vesicular to hollow inside. Actual shape of bombs varies greatly, and is used in descriptive classification, e.g., rotational bomb; spindle bomb.
Box canyon	a) A narrow gorge or canyon containing an intermittent stream following a zigzag course, characterized by high, steep rock walls and typically closed upstream by a similar wall, giving the impression, as viewed from its bottom, of being surrounded or “boxed in” by almost vertical walls. b) A steep-walled canyon heading against a cliff a dead-end canyon.
Braided stream	A channel or stream with multiple channels that interweave as a result of repeated bifurcation and convergence of flow around inter-channel bars, resembling (in plan view) the strands of a complex braid. Braiding is generally confined to broad, shallow streams of low sinuosity, high bed load, non-cohesive bank material, and

Term	Definition
	a steep gradient. At a given bank-full discharge, braided streams have steeper slopes and shallower, broader, and less stable channel cross sections than meandering streams.
Break	An abrupt change or inflection in a slope or profile (as in “a break in slope”). knickpoint, shoulder, escarpment. (geomorphology) A marked variation of topography, or a tract of land distinct from adjacent land, or an irregular or rough piece of ground.
Breaks	(colloquial: western USA) A landscape or large tract of steep, rough or broken land dissected by ravines and gullies and marks a sudden change in topography as from an elevated plain to lower hilly terrain, or a line of irregular cliffs at the edge of a mesa or a river (e.g., the Missouri River breaks)
Broad interstream divide	(colloquial: southeastern USA) A type of very wide, low gradient (level to nearly level) interfluve that lacks a well developed drainage network such that large portions of the local upland lack stream channels or other drainageways; extensive in lower coastal plains and some lake plains, till plains and alluvial plain remnants.
Butte	An isolated, generally flat-topped hill or mountain with relatively steep slopes and talus or precipitous cliffs and characterized by summit width that is less than the height of bounding escarpments, commonly topped by a caprock of resistant material and representing an erosion remnant carved from flat-lying rocks.
Caldera	A large, more or less circular depression, formed by explosion and/or collapse, which surrounds a volcanic vent or vents, and whose diameter is many times greater than that of the included vent, or vents.
Canyon	A long, deep, narrow, very steep-sided valley cut primarily in bedrock with high and precipitous walls in an area of high local relief (e.g., mountain or high plateau terrain), often with a perennial stream at the bottom; similar to but larger than a gorge.
Canyon bench	One of a series of relatively narrow, flat landforms occurring along a canyon wall and caused by differential erosion of alternating strong and weak horizontal strata; a type of structural bench.
Canyonlands	A deeply and extensively dissected landscape composed predominantly of relatively narrow, steep-walled valleys with small flood plains or valley floors; commonly with considerable outcrops of hard bedrock on steep slopes, ledges, or cliffs, and with broader summits or interfluves than found in badlands. Side slopes exhibit extensive erosion, active back-wearing, and relatively sparse vegetation.
Captured stream	A stream whose course has been diverted into the channel of another stream by natural processes.
Centripetal drainage pattern	A drainage pattern in which the streams converge inward toward a central depression; generally indicative of a structural basin, volcanic crater, caldera, breached dome, bolson, or the end of an eroded anticline or syncline.
Channel	(a) [stream] The hollow bed where a natural body of surface water flows or may flow. The deepest or central part of the bed of a stream, containing the main current and occupied more or less continuously by water. (b) (colloquial: western U.S.A.) The bed of a single or braided watercourse that commonly is barren of vegetation and is formed of modern alluvium. Channels may be enclosed by banks or splayed across and slightly mounded above a fan surface and include bars and mounds of cobbles and stones. (c) [Microfeature] Small, trough-like, arcuate or sinuous channels separated by small bars or ridges, caused by fluvial processes; common to flood plains and young alluvial terraces; a constituent part of bar and channel topography.
Chasm/abyss/abime	(a) A deep breach, cleft or opening in the Earth's surface , such as a yawning fissure or narrow gorge. (b) A deep, very elongated gap in the floor of a cave.
Chenier	A long, narrow, vegetated marine beach ridge or sandy hummock, 1 to 6 m high, forming roughly parallel to a prograding shoreline seaward of marsh and mud-flat deposits, enclosed on the seaward side by fine-grained sediments, and resting on foreshore or mud-flat deposits. It is well drained, often supporting trees on higher areas. Widths range from 45 - 450 m and lengths may exceed several tens of kilometers

Term	Definition
Chenier plain	A mud-rich strand plain, occupied by cheniers and intervening mud-flats with marsh and swamp vegetation.
Cinder cone	A conical hill formed by the accumulation of cinders and other pyroclastics, normally basaltic or andesitic composition. Slopes generally exceed 20 percent.
Circle	A form of patterned ground whose horizontal mesh is dominantly circular.
Cirque	A steep-walled, half bowl-like recess or hollow, crescent-shaped or semicircular in plan, commonly situated at the head of a glaciated mountain valley or high on the side of a mountain, and produced by the erosive activity of a mountain glacier. It often contains a small round lake (tarn).
Cirque floor	The comparatively level bottom of a cirque, thinly mantled with till and consisting of glaciallyscoured knolls and hillocks separated by depressions, flat areas and small lakes (tarn); commonly it is bounded by a slightly elevated rock lip at its exit.
Cirque headwall	The glacially-scoured, steep and arcuate side or wall of a cirque, dominated by rockoutcrops, rubble, and colluvium.
Cirque platform	A relatively level or bench-like surface formed by the coalescence of several cirques.
Cliff	Any high, very steep to perpendicular or overhanging face of rock or earth; a precipice.
Climbing dune	A dune formed by the piling-up of sand by wind against a cliff or mountain slope; very common in arid regions with substantial local relief and strong, prevailing winds.
Closed depression	A generic name for any enclosed area that has no surface drainage outlet and from which water escapes only by evaporation or subsurface drainage; an area of lower ground indicated on a topographic map by a hachured contour line forming a closed loop.
Coastal plain	A low, generally broad plain that has as its margin an oceanic shore and its strata horizontal or gently sloping toward the water, and generally represents a strip of recently prograded or emerged sea floor; e.g. the coastal plain of the southeastern U.S. which extends for 3000 km from New Jersey to Texas.
Cockpit	A crudely star-shaped, closed depression (i.e. large sinkhole) in tropical karst having an inverted conical or slightly concave floor, with an irregular or serrate perimeter formed by subsidiary solution channels and corridors into adjacent hills, and surrounded by residual hills with steep, concave side slopes; the dominant type of closed depression in cockpit karst.
Cockpit karst	A karst landscape dominated by subsurface drainage and serrate or star-shaped depressions (cockpits) that range widely in size and density but typically are considerably larger than sinkholes (dolines),and are separated by intermediate residual hills with concave side slopes; a common type of tropical karst (e.g. Jamaica).
Col	A high, narrow, sharp-edged pass or saddle through a divide or between two adjacent peaks in a mountain range; especially a deep pass formed by the headward erosion and intersection of two cirques.
Collapse sinkhole	A type of sinkhole that is formed by collapse of a cave within the underlying soluble bedrock (e.g., limestone, gypsum, salt).
Collapsed ice-floored lakebed	A lakebed formed in a lake on glacial ice and subsequently "let down" or collapsed by the melting of underlying ice, resulting in contortion or folding of the lacustrine sediment and sedimentary structures. These modified or distorted lacustrine sediments cap present-day topographic highs and generally lie at elevations higher than the surrounding disintegration moraine.
Collapsed ice-walled lakebed	A lakebed that formed in a lake bounded by stagnant ice, but floored by solid ground, usually till. Collapse features are limited to the lakebed margins. Presently, these materials and sedimentary structures generally occur as roughly circular-shaped hills of till capped by lacustrine sediments, generally at elevations higher than surrounding disintegration moraine.
Collapsed lake plain	A lake plain formed on, and bounded by, glacial ice and subsequently "let down" or collapsed by the melting of underlying ice resulting in contortion or folding of the sediments and sedimentary structures. Lacustrine sediments cap present topography.

Term	Definition
Collapsed outwash plain	An outwash plain which forms on glacial ice (inside the glacial margin), and is subsequently let down or collapsed when the underlying ice melts, resulting in contortion or folding of the sediments and sedimentary structures to the extent that little of the original plain or it's gradient remain. Outwash sediments commonly cap present-day topography.
Colluvial apron	A landform with a concave to planar surface composed of a thick wedge-shaped deposit of colluvium and/or slope alluvium that forms the base (footslope) of a bluff, escarpment or steep slope .
Columnar joints	Parallel, prismatic columns, polygonal in cross-section, in basaltic flows and sometimes in other extrusive and intrusive rocks. They form as a result of contraction during cooling.
Cone karst	A variety of kegel karst topography, common in the tropics (e.g. Puerto Rico, Pacific Basin Islands) characterized by steep-sided, cone-shaped residual hills and ridges separated by star-shaped depressions, broader valleys, or lagoons. These hills and ridges have steep, convex side slopes and rounded tops that are dissected into secondary karst surfaces with shafts and various forms of karren microfeatures.
Constructional geomorphic surface	A geomorphic surface that owes its origin, form, position, or general character to depositional (aggradational) processes, such as the accumulation of sediment.
Constructional landform	Said of a landform that owes its origin, form, position, or general character to depositional (aggradational) processes, such as the accumulation of sediment (e.g., alluvial fan, volcanic cone).
Continental glacier	A glacier of considerable thickness completely covering a large part of a continent or an area of at least 50,000 square km, obscuring the underlying surface, such as the ice sheets covering Antarctica or Greenland. Continental glaciers occupied northern portions of the coterminous USA and Alaska in the past (e.g., Pleistocene) and usage ommonly implies former continental glacier conditions.
Coral island	a) A relict coral reef that stands above sea level and surrounded by water (e.g. Florida Keys). Carbonate sands rich in coral and shell fragments generally mantle the underlying flat coral platform. b) An oceanic island formed from coral accumulations lying atop or fringing volcanic peaks or platforms.
Corrosion surface	An area subjected to a process of erosion whereby rocks and soil are removed or worn away by natural chemical processes, especially by the solvent action of running water, but also by other reactions, such as hydrolysis, hydration, carbonation, and oxidation.
Coulee	(colloquial: northwest USA, and ND) A dry or intermittent stream valley or wash with an underfit stream, especially a long, steep-walled gorge representing a Pleistocene overflow channel that carried meltwater from an ice sheet; e.g. the Grand Coulee in Washington State.
Cove	(a) A small, narrow sheltered bay, inlet, creek or recess in an estuary, often inside a larger embayment. (b) A small, often circular, wave-cut indentation in a cliff; it usually has a restricted or narrow entrance. (c) A fairly broad, looped embayment in a lake shoreline. (d) A shallow tidal river, or the backwater near the mouth of a tidal river. (e) A walled and rounded or cirque-like opening at the head of a small steep valley. (f) (colloquial - southern Appalachians, USA) A smooth-floored, somewhat oval-shaped "valley" sheltered by hills or mountains; e.g., Cades Cove in eastern Tennessee.
Crag and tail	An elongate hill or ridge of subglacially streamlined drift, having at the stoss end (up-ice) a steep, often precipitous face or knob of ice-smoothed, resistant bedrock (the "crag") obstructing the movement of the glacier, and at the lee end (down-ice) a tapering, streamlined, gentle slope (the "tail") of intact, weaker rock and / or drift protected by the crag; also called lee-side cone.
Crater	A basin-like, rimmed structure, usually at the summit of a volcanic cone. It may be formed by collapse, by an explosive eruption or by the gradual accumulation of pyroclastic material into a surrounding rim.
Crater lake	A lake, usually of fresh water, that has formed in a volcanic crater or caldera by the accumulation of rain or groundwater
Creep	The process, surficial sediments, (creep deposit) and/or landform that results from

Term	Definition
	very slow downslope mass wasting of unconsolidated earthy material driven primarily by gravity, but facilitated by water saturation and by and freeze-thaw. Sometimes redundantly called soil creep.
Crest	A geomorphic component of hills consisting of the convex slopes (perpendicular to the contour) that form the narrow, roughly linear top area of a hill, ridge, or other upland where shoulders have converged to the extent that little or no summit remains; dominated by erosion, slope wash and mass movement processes and sediments (e.g., slope alluvium, creep). Commonly, soils on crests are more similar to those on side slopes than to soils on adjacent interfluves.
Crevasse	(a) A wide breach or crack in the bank of a river or canal; especially one in a natural levee or an artificial bank of the lower Mississippi River. (b) A wide, deep break or fissure in the Earth after an earthquake. A deep, nearly vertical fissure, crack, or rift in a glacier or other mass of land ice.
Crevasse filling	A short, straight ridge of stratified sand and gravel believed to have been deposited in a crevasse of a wasting glacier and left standing after the ice melted; a variety of kame. May also occur as long, sinuous ridges and linear complexes of till or drift.
Crevasse splay	A low energy delta, oriented perpendicular to a main channel, formed by a breack in a natural levee during flooding stage.
Cryoplanation surface	A land surface reduced and modified by processes associated with intensive forst action, such as solifluction, supplemented by the erosive and trasnport actions of running water, moving ice, and other agents
Cuesta	An asymmetric ridge capped by resistant rock layers of slight to moderate dip, commonly less than 10º (approximately < 15 percent); a homocline type produced by differential erosion of interbedded resistant and weak rocks. A cuesta has a long, gentle slope on one side (dip slope), that roughly parallels the inclined beds, and on the opposite side has a relatively short, steep or cliff-like slope (scarp slope) that cuts the tilted rocks.
Cuesta valley	An asymmetric depression adjacent to a cuesta that lies parallels to the strike of the underlying strata; a type of strike valley. It's formed by differential erosion of weaker strata interbedded with, or stratigraphically adjacent to more resistant rocks. It may or may not contain a local drainage network but commonly lies above and is unconnected to the regional drainage system.
Cutter	A dissolution groove or trench formed along vertical bedrock fractures beneath soil and usually buried beneath regolith with little or no ground surface expression, commonly wider than a solution fissure (widths commonly range from 0.5 to 3 meters) and tapering down to a crack or a bedrock floored trench; also called grike (not preferred), or subsurface karren.
Debris avalanche	The process, associated sediments (debris avalanche deposit) or resultant landform characterized by a very rapid to extremely rapid type of flow dominated by the sudden downslope movement of incoherent, unsorted mixtures of soil and weathered bedrock which, although comparatively dry, behave much as a viscous fluid when moving.
Debris fall	The process, associated sediments (debris fall deposit) or resultant landform characterized by a rapid type of fall involving the relatively free, downslope movement or collapse of detached, unconsolidated material which falls freely through the air (lacks an underlying slip face); sediments have substantial proportions of both fine earth and coarse fragments; common along undercut stream banks.
Debris flow	The process, associated sediments (debris flow deposit) or resultant landform characterized by a very rapid type of flow dominated by a sudden downslope movement of a mass of rock, soil, and mud (more than 50% of the particles are > 2mm), and whether saturated or comparatively dry, behaves much as a viscous fluid when moving.
Debris slide	The process, associated sediments (debris slide deposit) or resultant landform characterized by a rapid type of slide, composed of comparatively dry and largely unconsolidated earthy material which slides or rolls downslope (does not exhibit backward rotation) and resulting in an irregular, hummocky deposit somewhat

Term	Definition
	resembling a moraine.
Debris spread	The process, associated sediments (debris spread deposit) or resultant landforms characterized by a very rapid type of spread dominated by lateral movement in a soil and rock mass resulting from liquefaction or plastic flow of underlying materials that may be extruded out between intact units; sediments have substantial proportions of both fine earth and coarse fragments.
Debris topple	The process, associated sediments (debris topple deposit) or resultant landform characterized by a localized, very rapid type of topple in which large blocks of soil and rock material literally fall over, rotating outward over a low pivot point; sediments have substantial proportions of both fine earth and coarse fragments. Portions of the original material may remain intact, although reoriented, within the resulting debris pile.
Deflation basin	A topographic basin excavated and maintained by wind erosion which removes unconsolidated material.
Delta	A body of alluvium, nearly flat and fan-shaped, deposited at or near the mouth of a river or stream where it enters a body of relatively quiet water, usually a sea or lake.
Delta plain	The level or nearly level surface composing the land-ward part of a large delta; strictly, a flood plain characterized by repeated channel bifurcation and divergence, multiple distributary channels, and interdistributary flood basins.
Dendritic drainage pattern	A common drainage pattern in which the tributaries join the gently curving mainstream at acute angles, resembling in plan view the branching habit of an oak or chestnut tree; it is produced where a consequent stream receives several tributaries which in turn are fed by smaller tributaries. It indicates streams flowing across horizontal rock strata and homogenous soil typified by the landforms of soft sedimentary rocks, volcanic tuff, old dissected coastal plains, or complex crystalline rocks offering uniform resistance to erosion.
Depression	Any relatively sunken part of the Earth's surface; especially a low-lying area surrounded by higher ground. A closed depression has no natural outlet for surface drainage (e.g. a sinkhole). An open depression has a natural outlet for surface drainage.
Deranged drainage pattern	A distinctively disordered drainage pattern of nonintegrated streams which indicates a complete lack of underlying structural and bedrock control, resulting from a relatively young landscape having a flat or undulating topographic surface and a high water table. It is characterized by relatively few, irregular streams with few, short tributaries, that flow into and out of depressions containing swamps, bogs, marshes, ponds, or lakes; interstream areas are swampy. Regional streams may meander through the area but do not influence its drainage. These drainage patterns commonly occur on young, thick till plains, end moraines, flood plains, and coastal plains.
Desert pavement/Reg	A natural, residual concentration or layer of wind-polished, closely packed gravel, boulders, and other rock fragments, mantling a desert surface. It is formed where wind action and sheetwash have removed all smaller particles or where coarse fragments have migrated upward through sediments to the surface. It usually protects the underlying, finer-grained material from further deflation.
Destructional landform	Said of a landform that owes its origin, form, position, or general character to the removal of material by erosion and weathering (degradation) processes resulting from the wearing-down or away of the land surface.
Dip slope	A slope of the land surface, roughly determined by and approximately conforming to the dip of underlying bedded rocks; (i.e. the long, gently inclined surface of a cuesta).
Disintegration moraine	A drift topography characterized by chaotic mounds and pits, generally randomly oriented, developed in supraglacial drift by collapse and flow as the underlying stagnant ice melted. Slopes may be steep and unstable and there will be used and unused stream courses and lake depressions interspersed with the morainic ridges. Characteristically, there are numerous abrupt, lateral and vertical changes between unconsolidated materials of differing lithology.
Distributary channel	(a) A divergent stream flowing away from the main stream and not returning to it,

Term	Definition
	as in a delta or on a flood plain. It may be produced by stream deposition choking the original channel. (b) One of the channels of a braided stream; a channel carrying the water of a stream distributary.
Dome	A smootly rounded landform or rock mass, such as a rock-capped mountain summit, that roughly ressembles the dome of a building.
Drainage pattern	The configuration or arrangement, in plan view, of stream courses in an area, including gullies or first-order channelized flow areas, higher order tributaries, and main streams. Drainage pattern is related to local geologic materials and structure, geomorphologic features, and geomorphic history of an area; major drainage pattern types include dendritic, trellis, artificial, etc. Also called drainage network.
Drainageway	(a) A general term for a course or channel along which water moves in draining an area. (b) [soil survey] a term restricted to relatively small, roughly linear or arcuate depressions that move concentrated water at some time, and either lack a defined channel (e.g. head slope, swale) or have a small, defined channel (e.g. low order streams).
Drainhead complex	An irregular series of low, broad depressions that form the uppermost reaches of surface drainage networks in low relief / low gradient terrain such as coastal plains, and separated by slightly higher and drier areas (e.g. flatwoods). They characteristically lack defined stream channels but contribute surface water to the drainage system further downstream through a network of subtle topographic lows.
Drumlin	A low, smooth, elongated oval hill, mound, or ridge of compact till that has a core of bedrock or drift. It usually has a blunt nose facing the direction from which the ice approached and a gentler slope tapering in the other direction. The longest axis is parallel to the general direction of glacier flow. Drumlins are products of streamline (laminar) flow of glaciers, which molded the subglacial floor through a combination of erosion and deposition.
Drumlin field	Groups or clusters of closely spaced drumlins or drumlinoid ridges, distributed more or less en echelon, and commonly separated by small, marshy tracts or depressions (interdrumlins).
Drumlinoid ridge	A rock drumlin or drift deposit whose form approaches but does not fully attain that of a classic drumlin, even though it seemingly results from similar processes of moving ice.
Dune	A low mound, ridge, bank or hill of loose, windblown, subaerially deposited granular material (generally sand), either barren and capable of movement from place to place, or covered and stabilized with vegetation, but retaining its characteristic shape.
Dune field	An assemblage of moving and/or stabilized dunes, together with sand plains, interdune areas, and the ponds, lakes, or swamps produced by the blocking of waterways by migrating dunes.
Dune lake	(a) A lake occupying a deflation basin as in a blowout on a dune. (b) A lake occupying a basin formed by the blocking of a stream by sand dunes migrating along a shore (e.g. Moses lake, WA).
Dune slack	A damp depression or trough between dunes in a dune field or dune ridges on a shore, caused by intersecting the capillary fringe of the local water table; a moist type of interdune.dune lake.
Dune traces	A series of linear to semi-concentric micro-ridges and intervening troughs, on the floor of a dune slack or interdune that were exposed by deflation or dune migration. The ridges are remnant bases of slip face lamina held together by soil moisture and /or cemented by evaporites.
Earth hummock	A type of hummock consisting predominantly of a core of silty and clayey mineral soil and showing evidence of cryoturbation. Earth hummocks are a type of nonsorted circle.
Earth pillar	A tall, conical column of unconsolidated to semi-consolidated earth materials (e.g. clay till, or landslide debris) produced by differential erosion and usually capped by a flat, hard rock fragment that shields the underlying, softer material from erosion. It can measure up to 6-20 m in height, and its diameter is a function of the width of

Term	Definition
	the protective boulder.
Earth spread	The process, associated sediments (earth spread deposit) or resultant landforms characterized by a very rapid type of spread dominated by lateral movement in a soil mass resulting from liquefaction or plastic flow of underlying materials that may be extruded out between intact units.
Earth topple	The process, associated sediments (earth topple deposit) or resultant landform characterized by a localized, very rapid type of topple in which large blocks of soil material literally fall over, rotating outward over a low pivot point; sediments < 2 mm predominate. Portions of the original material may remain intact, although reoriented, within the resulting deposit.
Earthflow	The process, associated sediments (earthflow deposit), or resultant landform characterized by slow to rapid flow dominated by downslope movement of soil, rock, and mud (more than 50% of the particles are < 2 mm), and whether saturated or comparatively dry, behaves as a viscous fluid when moving.
Ebb-tidal delta	A tidal delta formed at the seaward side of a tidal inlet
End moraine	A ridge-like accumulation that is being or was produced at the outer margin of an actively flowing glacier at any given time; a moraine that has been deposited at the outer or lower end of a valley glacier.
Endoreic	Said of a basin or region characterized internal drainage; relating to endorheism.
Ephemeral stream	Generally a small stream, or upper reach of a stream, that flows only in direct response to precipitation. It receives no protracted water supply from melting snow or other sources and its channel is above the water table at all times.
Eroded fan remnant	All, or a portion of an alluvial fan that is much more extensively eroded and dissected than a fan remnant; sometimes called an erosional fan remnant (FFP). It consists primarily of a) eroded and highly dissected sides (eroded fan-remnant sideslopes) dominated by hillslope positions (shoulder, backslope, etc.), and b) to a lesser extent an intact, relatively planar, relict alluvial fan “summit” area best described as a tread.
Eroded fan-remnant sideslope	A rough or broken margin of an eroded fan remnant highly dissected by ravines and gullies that can be just a fringe or make up a large part of an eroded alluvial fan; its bounding escarpments (risers), originally formed by inset channels, have become highly dissected and irregular such that terrace components (tread and riser) have been consumed or modified and replaced by hillslope positions and components (shoulder, backslope, footslope, etc.); sometimes referred to as fan remnant sideslopes.
Erosion pavement	A surficial lag concentration or layer of gravel and other rock fragments that remains on the soil surface after sheet or rill erosion or wind has removed the finer soil particles and that tends to protect the underlying soil from further erosion.
Erosion plain	A general term for any plain produced by erosion, such as a peneplain, a pediplain, or a plain of marine erosion.
Erosion platform	(a) A relatively level surface of limited extent formed by shore-zone erosion. (b) A wave-cut platform along the coast.
Erosion remnant	A topographic feature that remains or is left standing above the general land surface after erosion has reduced the surrounding area; e.g., a monadnock, a butte, or a stack.
Erosion scarp	A scarp produced by erosion; e.g. a fault-line scarp or a beach scarp.
Erosion surface	A land surface shaped by the action of erosion, especially by running water.
Erosional geomorphic surface	A geomorphic surface that owes its origin, form, position or general character to degradational processes by water, wind, ice or gravity.
Erratic block	A rock fragment carried by glacial ice, or by floating ice (ice-rafting), and subsequently deposited at some distance from the outcrop from which it was derived, and generally, though not necessarily, resting on bedrock or sediments of different lithology. Coarse fragments range in size from a pebble to a house-size block.
Escarpment	A relatively continuous and steep slope or cliff produced by erosion or faulting and that topographically interrupts or breaks the general continuity of more gently sloping land surfaces . The term is most commonly applied to cliffs produced by differential erosion. Synonym: "scarp."

Term	Definition
Esker	A long, narrow, sinuous and steep-sided ridge composed of irregularly stratified sand and gravel deposited by a subglacial or englacial stream flowing between ice walls or in an ice tunnel of a stagnant or retreating glacier, and was left behind when the ice melted. It may be branching and is often discontinupus, and its course can be at a high angle to the edge of the glacier. Eskers range in lenght from less than 100 m. to more than 500 km (if gaps are included), and in height from 3 to more than 200 m.
Estuary	(a) A seaward end or the widened funnel-shaped tidal mouth of a river valley where fresh water comes into contact with seawater and where tidal effects are evident; e.g., a tidal river, or a partially enclosed coastal body of water where the tide meets the current of a stream. (b) A portion of an ocean or an arm of the sea affected by fresh water. (c) A drowned river mouth formed by the subsidence of land near the coast or by the drowning of the lower portion of a non-glacial valley due to the rise of sea level.
Exhumed	Formerly buried landforms, geomorphic surfaces, or paleosols that have been reexposed by erosion of the covering mantle.
Exokarst	All features found on the surface of a karst landscape, ranging in size from tiny karren forms to extensive poljes
Extra-marginal valley	Valley formed by glacial melt water in front of the glacier
Faceted spur	The inverted V-shaped end of a ridge that has been truncated or steeply beveled by steam erosion (e.g. meander scar or bluff), glacial truncation, or fault scarp displacement.
Fall	(a) A category of mass movement processes, associated sediments (fall deposit), or resultant landforms (e.g., rock fall, debris fall, soil fall) characterized by very rapid movement of a mass of rock or earth that travels mostly through the air by free fall, leaping, bounding, or rolling, with little or no interaction between one moving unit and another.
Falling dune	An accumulation of sand that is formed as sand is blown off a mesa top or over a cliff face or steep slope, forming a solid wall, sloping at the angle of repose of dry sand, or a fan extending downward from a re-entrant in the mesa wall.
Fan	(a) A gently sloping, fan-shaped mass of detritus forming a section of a low-angle cone commonly at a place where there is a notable decrease in gradient; specifically an alluvial fan (not preferred – use alluvial fan). (b) A fan-shaped mass of congealed lava that formed on a steep slope by the continually changing direction of flow.
Fan apron	A sheet-like mantle of relatively young alluvium and soils covering part of an older fan piedmont (and occasionally alluvial fan) surface, commonly thicker and further down slope (e.g., mid-fan or mid-fan piedmont) than a fan collar. It somewhere buries an older soil that can be traced to the edge of the fan apron where the older soil emerges as the land surface, or relict soil. No buried soils should occur within a fan apron mantle itself.
Fan collar	A landform comprised of a thin, short, relatively young mantle of alluvium along the very upper margin (near the proximal end or apex) of a major alluvial fan. The young mantle somewhere buries an older soil that can be traced to the edge of the collar where the older soil emerges at the land surface as a relict soil.
Fan piedmont	The most extensive landform on piedmont slopes, formed by (a) the lateral, downslope, coalescence of mountain-front alluvial fans into one generally smooth slope with or without the transverse undulations of the semi-conical alluvial fans, and (b) accretions of fan aprons.
Fan remnant	A general term for landforms that are the remaining parts of older fan-landforms, such as alluvial fans, fan aprons, inset fans, and fan skirts, that either have been dissected (erosional fan-remnants) or partially buried (nonburied fan-remnants). An erosional fan remnant must have a relatively flat summit that is a relict fan-surface. A nonburied fan-remnant is a relict surface in its entirety.
Fan skirt	The zone of smooth, laterally-coalescing, small alluvial fans that issue from gullies cut into the fan piedmont of a basin or that are coalescing extensions of the inset fans of the fan piedmont, and that merge with the basin floor at their toeslopes. These are generally younger fans which onlap older fan surfaces.

Term	Definition
Fanhead trench	A linear depression formed by a drainageway that is incised considerably below the surface of an alluvial fan.
Fault-block mountains	Mountains that formed primarily by block faulting, and commonly exhibit asymmetrical rotation and vertical displacement from a horizontal plane by large, coherent fault-block units hinged along fault lines; common in , but not limited to, the Basin and Range region of the US.. The term is not applied to mountains formed by thrust-faulting.
Fault-line scarp	(a) A steep slope or cliff formed by differential erosion along a fault line, as by the more rapid erosion of soft rock on the side of a fault as compared to that of more resistant rock on the other side; e.g. the east face of the Sierra Nevada in California. (b) (not recommended) A fault scarp that has been modified by erosion. This usage is not recommended because the scarp is usually not located on the fault line.
Finger ridge	One in a group of small, tertiary spur ridges that form crudely palmate extensions of erosional remnants along the flanks or nose of larger ridges.
Fissure	A surface of fracture or a crack in rock along which there is a distinct separation
Fissure vent	An opening in earth's surface of a volcanic conduit in the form of a crack or fissure rather than a localized crater; a roughly linear crack or area along which lava, generally mafic and of low viscosity, wells up to the surface, usually without any explosive activity. The results can be an extensive lava plateau (e.g.Columbia River Plateau).
Fissure volcano	One of a series of volcanic vents in a pattern of eruption along a fissure.
Fjord	A long, narrow, winding, glacially eroded, U-shaped and steep-walled, generally deep inlet or arm of the sea between high rocky cliffs of slopes along a mountainous coast. Typically it has a shallow sill or threshold of solid rock or earth material submerged near its mouth and becomes deeper far inland. A fjord usually represents the seaward end of a deep, glacially excavated valley that is partially submerged by drowning after melting of the ice.
Flat	(a) (adjective) Said of an area characterized by a continuous surface or stretch of land that is smooth, even, or horizontal, or nearly so, and that lacks any significant curvature, slope, elevations, or depressions. (b) (noun) An informal, generic term for a level or nearly level surface or small area of land marked by little or no local relief. Compare - mud flat. (c) (not recommended) A nearly level region that visibly displays less relief than its surroundings.
Flat plains	A group of fundamental, three dimensional pieces or areas of flat plains. In descending elevational order, the geomorphic components of a simple, flat plain (e.g. lake plain, low coastal plain, etc.) are the rise [a broad, slightly elevated area with comparatively greater gradients (e.g., 1-3% slopes], and the talf [a comparatively level (e.g., 0-1% slopes), laterally extensive, non-fluvial area], and dip [a slight depression that is not a permanent water body nor part of an integrated drainage network].
Flood plain	The nearly level plain that borders a stream and is subject to inundation under flood-stage conditions unless protected artificially. It is usually a constructional landform built of sediment deposited during overflow and lateral migration of the streams.
Flood-plain landforms	A variety of constructional and erosional features produced by stream channelmigration and flooding, e.g., backswamp, braided stream, flood-plain splay, meander, meander belt, meander scroll, oxbow lake, and natural levee.
Flood-plain playa	A landform consisting of very low gradient, broad, barren, axial-stream channel segments in an intermontane basin. It floods broadly and shallowly and is veneered with barren fine-textured sediment that crusts. Commonly, a flood-plain playa is segmented by transverse, narrow bands of vegetation, and it may alternate with ordinary narrow or braided channel segments.
Flood-plain splay	A fan-shaped deposit or other outspread deposit formed where an overloaded stream breaks through a levee (natural or artificial) and deposits its material (often coarse-grained) on the flood plain.
Flood-plain step	An essentially flat, terrace-like alluvial surface within a valley that is frequently covered by flood water from the present stream (e.g., below the 100 year flood

Term	Definition
	level); any approximately horizontal surface still actively modified by fluvial scour and/or deposition (i.e., cut and fill and/or scour and fill processes). May occur individually or as a series of steps.
Flood-prone area	Land on a flood plain that is subject to inundation during a flood of a designated frequency or magnitude; for exemple, a 100-year flood or a standard project flood.
Flood-tidal delta	A tidal delta formed at the landward side of a tidal inlet
Flow	A category of mass movement processes, associated sediments (flow deposit) and landforms characterized by slow to very rapid downslope movement of unconsolidated material which, whether saturated or comparatively dry, behaves much as a viscous fluid as it moves. Types of flows can be specified based on the dominant particle size of sediments (i.e. debris flow (e.g., lahar), earth flow (creep, mudflow), rock fragment flow (e.g., rockfall avalanche), debris avalanche].
Flute	A lineation or streamlined furrow or ridge parallel to the direction of ice movement, formed in newly deposited till or older drift. They range in height from a few centimeters to 25 m, and in length from a few meters to 20 km.
Fluvial terrace	Elongate terraces that flank the sides of floodplains and fluvial valleys. They consist of a relatively level strip of land, called a “tread,” separated from either an adjacent floodplain, other fluvial terraces, or uplands by distinctly steeper strips of land called “risers.” These terraces lie parallel to and above the river channel and its floodplain
Fluviokarst	A karst landscape dominated by both 1) karst features (deranged and subsurface drainage, blind valleys, swallow holes, large springs, closed depressions, and caves), generally limited to low-lying interfluve areas, and 2) surface drainage by large rivers, with associated fluvial features (adjacent stream terraces) and sediments (alluvium), that commonly maintain their surface courses and are fed by underground tributaries; the dominant karst in the eastern USA.
Fluviomarine terrace	A constructional coastal strip, sloping gently seaward and/or down valley, veneered or completely composed of fluviomarine deposits (typically silt, sand, fine gravel).
Foothills	A steeply sloping upland composed of hills with relief of 30 up to 300 meters and fringes a mountain range or high-plateau escarpment.
Footslope	The hillslope profile position that forms the concave surface at the base of a hillslope. It is a transition zone between upslope sites of erosion and transport (shoulder, backslope) and downslope sites of deposition (toeslope).
Foredune	A coastal dune or dune ridge oriented parallel to the shoreline, occurring at the landward margin of the beach, along the shoreward face of a beach ridge, or at the landward limit of the highest tide, and more or less stabilized by vegetation.
Fosse	A long, narrow depression or trough-like hollow between the edge of a retreating glacier and the wall of its valley, or between the front of a moraine and its outwash plain.
Free face	A geomorphic component of hills and mountains consisting of an outcrop of bare rock that sheds rock fragments and other sediments to, and commonly stands more steeply than the angle of repose of, the colluvial slope immediately below; most commonly found on shoulder and backslope positions, and can comprise part or all of a nose slope or side slope.
Fringe-tidal marsh	Narrow salt marsh adjacent to a relatively higher energy environment.
Frost boil	A small mound of fresh soil material formed by frost action. A type of nonsorted circle commonly found in fine-grained sediment underlain by permafrost, or formed in areas affected by seasonal frost.
Gap	A sharp break or opening in a mountain ridge, or a short pass through a mountain range; e.g., a wind gap.
Geiser	A type of hot spring that intermittently erupts jets of hot water and steam, the result of ground water coming in contact with rock or steam hot enough to create steam under conditions preventing free circulation; a type of intermittent spring.
geomorphic component	A fundamental, three dimensional piece or area of a geomorphic setting (i.e., hills, mountains, terraces, flat plains) that has unique and prevailing kinetic energy dynamics and sediment transport conditions which result in their characteristic form, patterns of sedimentation and soil development.

Term	Definition
geomorphic component - flat plains	A group of fundamental, three dimensional pieces or areas of flat plains. In descending elevational order, the geomorphic components of a simple, flat plain (e.g. lake plain, low coastal plain, etc.) are the rise [a broad, slightly elevated area with comparatively greater gradients (e.g., 1-3% slopes], and the talf [a comparatively level (e.g., 0-1% slopes), laterally extensive, non-fluvial area], and dip [a slight depression that is not a permanent water body nor part of an integrated drainage network].
geomorphic component - hills	A set of fundamental, three-dimensional areas and positions that geomorphically define a hill or ridge. In descending topographic order, the geomorphic components are interfluve (stable summit area) ; crest (unstable summit - converged shoulders); three geometric slope areas defined by plan shape and its influence on overland flow and throughflow: These are: head slope (convergent flow), side slope (parallel flow), and nose slope (divergent flow); free face (rock outcrop); and base slope (concave accretion area (colluvium / slope alluvium) at hill bottom).
geomorphic component - mountains	A group of fundamental, three dimensional pieces or areas of mountains. In descending elevational order, the geomorphic components of a simple mountain are the mountaintop (roughly analogous to the crest or summit); mountainflank (the long slope along the sides of mountains which can be further subdivided into three portions based on the relative slope location: upper third-, middle third-, or lower third mountainflank); free face (rock outcrop); and the mountainbase (colluvium / slope alluvium apron at the bottom of the mountain).
geomorphic component – terraces, stepped landforms	A group of fundamental, three dimensional pieces or areas of terraces, flood-plain steps, and other stepped landforms (e.g. stacked lava flow units). In descending elevational order, the geomorphic components are the tread (the level to gently sloping, laterally extensive top of a terrace, flood-plain step, or other stepped landform); and the riser (the comparatively short escarpment forming the more steeply sloping edge that descends to another level or a channel).
Geomorphic surface	A mappable area of the earth's surface that has a common history; the area is of similar age and is formed by a set of processes during an episode of landscape evolution. A geomorphic surface can be erosional, constructional or both. The surface shape can be planar, concave, convex, or any combination of these.
Geyser basin	A valley that contains numerous springs, geysers, and steam fissures fed by the same groundwater flow.
Geyser cone	A low hill or mound built up of siliceous sinter around the orifice of a geyser.
Glacal stationary line	An interpretated line that marks the maximal extend of an ice sheet.
Glacial cirque	A deep steep-walled half-bowl-like recess or hollow, variously described as horseshoe- or crescent-shaped or semicircular in plain, situated high on the side of a mountain and commonly at the head of a glacial valley, and produced by the erosive activity of a mountain glacier. It often contains a small round lake, and it may or may not be occupied by ice or snow.
Glacial drainage channel	A channel formed by an ice-marginal, englacial, or subglacial stream during glaciation.
Glacial groove	A deep, wide, usually straight furrow cut in bedrock by the abrasive action of a rock fragment embedded in the bottom of a moving glacier; it is larger and deeper than a glacial striation, ranging in size from a deep scratch to a small glacial valley.
Glacial lake	(a) A lake that derives much or all of its water from the melting of glacier ice, fed by meltwater, and lying outside the glacier margins (e.g. proglacial lake) or lying on a glacier (e.g. ice-walled lake, icefloored lake) and due to differential melting. (b) A lake occupying a basin produced by glacial deposition, such as one held in by a morainal dam. (c) A lake occupying a basin produced in bedrock by glacial erosion (scouring, quarrying); e.g., cirque lake, fjord. (d) A lake occupying a basin produced by collapse of outwash material surrounding masses of stagnant ice. (e) [relict] An area formerly occupied by a glacial lake.
Glacial lineation	Any kind of glacially formed lineation that runs parallel to the direction of the glaciers movement.
Glacial valley	A usually, U shaped, steep-sided valley showing signs of glacial erosion; a

Term	Definition
	glaciatd valley, or one that has been modified by a glacier.
Glacial-valley floor	The comparatively flat bottom of a mountain valley predominantly mantled by till but which can grade from glacial scour (scoured rock-outcrop) near it's head to a thick mantle of till, and ultimately merging with alluvium or colluvium further down valley. Some glacial-valley floors descend downstream in a series of scour-derived steps which may contain sequential tarn lakes (pater noster lakes); (not preferred: colloquial – western USA) sometimes called a trough bottom.
Glacial-valley wall	The comparatively steep, glacially scoured, concave sides of a U-shaped, mountain valley mantled by colluvium with little or no till; (not preferred: colloquial – western USA) sometimes called a trough wall.
Glacier	a) A large mass of ice formed, at least in part, on land by the compaction and recrystallization of snow, moving slowly by creep downslope or outward in all directions due to the stress of its own weight, and surviving from year to year. Included are small mountain glaciers as well as ice sheets continental in size, and ice shelves which float on the ocean but are fed in part by ice formed on land. b) A stream-like landform having the appearance of, or moving like a glacier; e.g. a rock glacier.
Glaciokarst	Karst in glaciated terrain developed on bedrock susceptible to dissolution (e.g. limestone), thinly mantled (e.g. < 5 - 30 m) with glacial drift and characterized by surficial, closed depressions formed by post-glacial, subsurface karstic collapse (e.g. sinkholes) rather than by glacial processes (e.g. ice-block melt-out); common in IN, MI.
Gorge	(a) A narrow, deep valley with nearly vertical, rocky walls, smaller than a canyon, and more steepsided than a ravine; especially a restricted, steep-walled part of a canyon. (b) A narrow defile or passage between hills or mountains.
Granite blockfield	A block field where all the blocks are of granitic compostion.
Groove	A small, natural, narrow drainageway on high angle slopes which separate tertiary spur ridges or mini-interfluves and is a constituent part of rib and groove topography; common in well dissected uplands.
Ground moraine	(a) Commonly an extensive, low relief area of till, having an uneven or undulating surface, and commonly bounded on the distal end by a recessional or end moraine; (b) A layer of poorly sorted rock and mineral debris (till) dragged along, in, on, or beneath a glacier and deposited by processes including basal lodgment and release from downwasting stagnant ice by ablation.
Gulch	(colloquial: western U.S.A.; not preferred – refer to ravine) A small stream channel, narrow and steep-sided in cross section, and larger than a gully, cut in unconsolidated materials. General synonym - ravine.
Gulf	A relatively large part of an ocean or sea extending far into the land, partly enclosed by an extensive sweep of the coast, and opened to the sea through a strait (e.g. Gulf of Mexico); the largest of various forms of inlets of the sea. It is usually larger, more enclosed, and more deeply indented than a bay.
Gully	A small channel with steep sides caused by erosion and cut in unconsolidated materials by concentrated but intermittent flow of water usually during and immediately following heavy rains or ice /snow melt. A gully generally is an obstacle to wheeled vehicles and too deep (e.g., > 0.5 m) to be obliterated by ordinary tillage; (a rill is of lesser depth and can be smoothed over by ordinary tillage).
Gut	(a) (colloquial: U.S. Virgin Islands, Caribbean Basin) A gully, ravine, small valley, or narrow passage on land. (b) [stream] (not preferred – use tidal channel). A tidal stream connecting two larger waterways within a lagoon, estuary or bay.
Hanging valley	A tributary valley whose floor at the lower end is notably higher than the floor of the main valley in the area of junction.
Headland	(a) An irregularity of land, especially of considerable height with a steep cliff face, jutting out from the coast into a large body of water (usually the sea or a lake); a bold promontory or a high cape. (b) The high ground flanking a body of water, such as a cove. (c) The steep crag or cliff face of a promontory.
Head-of-outwash	A sloping and sometimes high relief landform composed predominantly of glaciofluvial sediment that delimits a former ice-margin of a relatively static, rapidly

Term	Definition
	wasting glacier. A steep ice-contact slope forms the ice-proximal face of the landform; a more gently sloping surface dips away on the distal slope, if not slumped.
Headwall	A steep slope at the head of a valley; e.g. the rock cliff at the back of a cirque.
Highmoor bog	A bog, often on the uplands, whose surface is covered by sphagnum mosses which, because of their high degree of water retention, make the bog more dependent upon precipitation than on the water table. The bog often occurs as a raised peat bog or blanket bog
Hills	A set of fundamental, three-dimensional areas and positions that geomorphically define a hill or ridge. In descending topographic order, the geomorphic components are interfluve (stable summit area) ; crest (unstable summit - converged shoulders); three geometric slope areas defined by plan shape and its influence on overland flow and hroughflow: These are: head slope (convergent flow), side slope (parallel flow), and nose slope (divergent flow); free face (rock outcrop); and base slope (concave accretion area (colluvium / slope alluvium) at hill bottom).
Hillslope	A generic term for the steeper part of a hill between its summit and the drainage line, valley flat, or depression floor at the base of the hill.
Hogback	A sharp-crested, symmetric ridge formed by highly tilted resistant rock layers; a type of homocline produced by differential erosion of interlayered resistant and weak rocks with dips greater than about 25 o (or approximately > 45 % slopes).
Homoclinal ridge	A homocline that forms an asymmetric ridge with a dip slope commonly between 10 to 25º (15 to 45 %). A homoclinal ridge has steeper dip than a cuesta, but lower dip than a hogback.
Hoodoo	(a) A fantastic column, pinnacle, or pillar of rock produced in a region of sporadic heavy rainfall by differential weathering or erosion of horizontal strata, facilited by joints and by layers of varying hardness, and occuring in varied and often eccentric or grotesque forms.
Hornito	A samll mound of spatter built on the back of a lava flow (generally pahoheohe) formed by the gradual accumulation of clots of lava ejected through an opening in the roof of an underlying lava tube.
Hot spring	A natural, geothermally heated spring whose temperature is above that of the human body.
Hummocky moraine	A strongly undulating surface of ground moraine also known as kame and kettle topography.
Ice wedge	A massive, generally wedge-shaped body with its apex pointing downward, composed of foliated or vertically banded, commonly white, ice.
Ice wedge cast	A filling of sediment in the space formerly occupied by an ice wedge.
Ice wedge polygon	Patterned ground in areas of ice wedges. These polygons are commonly in poorlydrained areas and may be high-centered or low-centered.
Ice-contact slope	A steep escarpment of predominantly glaciofluvial sediment that was deposited against a wall of glacier ice, marking the position of a relatively static ice-margin; an irregular scarp against which glacier ice once rested.
Ice-margin complex	An assemblage of landforms constructed proximal to a relatively static, rapidly wasting continental glacial margin. Constituent landforms can include fosse, head-of-outwash, ice-contact slope, ice-contact delta, kame, kame moraine, kettle, outwash fan, small outwash plain, glacial sluiceway, and small proglacial lake. Moraines, if present, are of limited occurrence (except kame moraines which can be extensive). Glaciofluvial sediments dominate but glaciolacustrine sediments, till, and diamictons can be present in minor amounts.
Ice-marginal stream	A stream drainage along the side or front of a glacier. Relict ice-marginal streams are used to trace the former position of a glacier; also called ice-marginal drainage.
Inselberg	A prominent, isolated, residual knob, hill, or small mountain, usually smoothed and rounded, rising abruptly from an extensive lowland erosion surface in a hot dry region; generally bare and rocky although the lower slopes are commonly buried by colluvium.
Inset fan	(colloquial; southwestern USA) The flood plain of an ephemeral stream that is

Term	Definition
	confined between the fan remnants, ballenas, basin-floor remnants, or closely-opposed fan toeslopes of a basin.
Integrated drainage	A general term for a drainage pattern in which stream systems have developed to the point where all parts of the landscape drain into some part of a stream system, the initial or original surfaces have essentially disappeared and the region drains to a common base level. Few or no closed drainage systems are present.
Interdrumlin	The concave to relatively flat bottomed, roughly linear depressions ranging from small saddles or swales to small valleys that separate drumlins or drumlinoid ridges in drumlin fields. Streams, if present, have not had a dominant impact on the formation of the depression.
Interdune	The relatively flat surface, whether sand-free or sand-covered, between dunes.
Interfluve	(a) A landform composed of the relatively undissected upland or ridge between two adjacent valleys containing streams flowing in the same general direction. An elevated area between two drainageways that sheds water to those drainageways. (b) A geomorphic component of hills consisting of the uppermost, comparatively level or gently sloped area of a hill; shoulders of backwearing hillslopes can narrow the upland (e.g., ridge) or merge (e.g., crest, saddle) resulting in a strongly convex shape.
Intermittent stream	A stream, or reach of a stream, that does not flow year-round (commonly dry for 3 or more months out of 12) and whose channel is generally below the local water table; it flows only when it receives a) base flow (i.e. solely during wet periods), or b) ground-water discharge or protracted contributions from melting snow or other erratic surface and shallow subsurface sources.
Intermontane basin	A generic term for wide structural depressions between mountain ranges that are partly filled with alluvium and called "valleys" in the vernacular. Intermontane basins may be drained internally (bolsons) or externally (semi-bolson).
Intertidal	The coastal environment between mean low tide and mean high tide that alternates between subaerial and subaqueous depending on the tidal cycle.
Island	(a) An area of land completely surrounded by water. (b) An elevated area of land surrounded by swamp, or marsh, or isolated at high water or during floods.
Kame	A low mound, knob, hummock, or short irregular ridge, composed of stratified sand and gravel deposited by a subglacial stream as a fan or delta at the margin of a melting glacier; by a supraglacial stream in a low place or hole on the surface of the glacier; or as a ponded deposit on the surface or at the margin of stagnant ice.
Kame field	A group of closely spaced kames, constiotuting a hilly landscape.
Kame moraine	(a) An end moraine that contains numerous kames. (b) A group of kames along the front of a stagnant glacier, commonly comprising the slumped or erosional remnants of a rmerly continuous outwash plain built up over the foot of rapidly wasting or stagnant ice.
Kame terrace	A terrace-like ridge consisting of stratified sand and gravel (a) deposited by a meltwater stream flowing between a melting glacier and a higher valley wall or lateral moraine, and (b) left standing after the disappearance of the ice. It is commonly pitted with "kettles" and has an irregular ice-contact slope.
Karren/Lapiaz	Repeating, surficial solution channels, grooves or other forms etched onto massive, bare limestone surfaces; types range in depth from a few millimeters to > 1 m and separated by ridges; the total complex (all varieties) of surficial solution forms found on compact, pure limestone. Many types can be specified.
Karst	A kind of topography formed in limestone, gypsum, or other soluble rocks by dissolution, and that is characterized by closed depressions, sinkholes, caves, and underground drainage. Various types of karst can be recognized depending upon the dominant surface features: karst dominated by closed depressions (sinkhole karst – temperate climates; cockpit karst – humid tropical climates), closed depressions and large rivers (fluviokarst), bare rock dominated by dissolution joints (pavement karst), tropical cone-, tower- or domed-hills (kegel karst), or karst thinly mantled with glacial drift (glaciokarst), etc.
Karst area	An area dominated by dissolution features (e.g., sinkhole, blind valley, closed depressions, underground drainage) formed in soluble rocks.

Term	Definition
Karst cone	A conically-shaped residual hill in karst with a rounded top and relatively steep, convex (e.g. parabolic) side slopes, commonly in tropical climates.
Karst drainage pattern	A drainage pattern that lacks an integrated drainage system associated with soluble rocks with little or no surface drainage but a considerable underground, internal drainage system; characteristic of karst landscapes underlain by limestone, gypsum, or salt.
Karst emergence/spring	In a karst region, the point where an underground stream appears at the surface to become a surface stream.
Karst feature	A geologic feature formed directly or indirectly by solution, including caves. The term is often used to describe features that are not large enough to be considered caves but have some probable relation to subsurface drainage or groundwater movement. These features typically incluide, but are not limited to, sinkholes, enlarged fractures, noncavernous springs and seeps, soil pipes, and epikarstic solution cavities.
Karst lake	A large area of standing water in an extensive closed depression in soluble bedrock (e.g. limestone) and commonly is directly connected to and controlled by the subsurface karst drainage network.
Karst tower	An isolated, separate hill or ridge in a karst region consisting of an erosional remnant of limestone or other sedimentary rocks with vertical or near-vertical, convex side slopes and commonly surrounded by an alluvial plain, lagoon, or deep rugged ravines.
Karst valley	(a) An elongate solution valley. (b) A valley produced by collapse of a cavern roof. (c) A closed depression dormed by the coalescence of several sinkholes. Its drainage is subsurface, its size is measured in hundreds of metres to a few kilometres, and ii usually has an irregular floor and a scaloped margin inherited from the sinkholes. Syn: nested sonkholes; solution valley; uvala.
Karst window	A collapse sinkhole opening into a cave. Syn: karst fenster.
Kegel karst	A general name used to describe several types of humid tropical karst landscapes characterized by numerous, closely spaced cone- (cone karst), hemispherical- (halbkugelkarst), or tower-shaped (tower karst) hills with vertical or near-vertical walls and having intervening closed depressions and narrow steepwalled karst valleys or passageways.
Kettle	A steep-sided, bowl-shaped depression commonly without surface drainage (closed depression) in drift deposits, often containing a lake or swamp, and formed by the melting of a large, detached block of stagnant ice that had been wholly or partly buried in the drift. Kettles range in depth from 1 to tens of meters, and with diameters up to 13 km
Knob	(a) A rounded eminence, a small hill or mountain; especially a prominent or isolated hill with steep sides, commonly found in the Southern United States. (b) A peak or other projection from the top of a hill or mountain. Also, a boulder or group of boulders or an area of resistant rocks protruding from the side of a hill or mountain.
Knoll	A small, low, rounded hill rising above adjacent landforms
Lagoon	(a) A shallow stretch of salt or brackish water, partly or completely separated from a sea or lake by an offshore reef, barrier island, sandbank or spit. (b) Relict landform: A nearly level, filled trough or depression behind the longshore bar on a barrier beach and built by a receding pluvial or glacial lake.
Lagoon channel	A subaqueous, sinuous area within a lagoon that likely represents a relict channel (paleochannel) (Wells et al., 1994) that is maintained by strong currents during tidal cycles (Short, 1975).
Lahar	The process, associated sediments or resultant landform characterized by a mudflow composed chiefly of volcaniclastic materials on or near the flank of a volcano. The debris carried in the flow includes pyroclastic material, blocks from primary lava flows, and epiclastic material. Thick flows can exhibit a crude (poorly sorted) upward-fining sediment sequence.
Lake	An inland body of permanently standing water fresh or saline, occupying a depression on the Earth's surface, generally of appreciable size (larger than a

Term	Definition
	pond) and too deep to permit vegetation (excluding subaqueous vegetation) to take root completely across the expanse of water.
Lake plain	A nearly level surface marking the floor of an extinct lake filled by well-sorted, generally finetextured, stratified deposits, commonly containing varves.
Lake terrace	A narrow shelf, partly cut and partly built, produced along a lake shore in front of a scarp line of low cliffs and later exposed when the water level falls.
Lakebed	(a) [relict] The flat to gently undulating ground underlain or composed of fine-grained sediments deposited in a former lake. (b) The bottom of a lake; a lake basin.
Lakeshore	The narrow strip of land in contact with or bordering a lake; especially the beach of a lake.
Landslide	A general, encompassing term for most types of mass movement landforms and processes involving the downslope transport and outward deposition of soil and rock materials, caused by gravitational forces and which may or may not involve saturated materials. Names of landslide types generally reflect the dominant process and/or the resultant landform. The main operational categories of mass movement are fall (rockfall, debris fall, soil fall), topple (rock topple, debris topple, soil topple), slide (rotational landslide, block glide, debris slide, lateral spread), flow [rock fragment flow (especially rockfall avalanche), debris avalanche, debris flow (e.g., lahar), earthflow, (creep, mudflow)], and complex landslides.
Lapilli tuff	An indurated deposit that is predominantly lapilli, with a matrix of ash.
Lateral moraine	A ridge-like moraine carried on and deposited at the side margin of a valley glacier. It is composed chiefly of rock fragments derived from valley walls by glacial abrasion and plucking, or colluvial accumulation from adjacent slopes.
Lateral spread	A category of mass movement processes, associated sediments (lateral spread deposit) or resultant landforms characterized by a very rapid spread dominated by lateral movement in a soil or fractured rock mass resulting from liquefaction or plastic flow of underlying materials; also called spread. Types of lateral spreads can be specified based on the dominant particle size of sediments (i.e. debris spread, earth spread, rock spread)
Lava cave	Any cave formed by volcanic processes.
Lava field	An area covered primarily by lava flows whose terrain can be rough and broken or relatively smooth; it can include vent structures (e.g., small cinder cones, spatter cones, etc.), surface flow structures (e.g., pressure ridges, tumuli, etc.) and small, intermittent areas covered with pyroclastics.
Lava flow	A lateral, surficial outpouring of molten lava from a vent or a fissure; also, the solidified body of rock that is so formed.
Lava levee	The scoriaceous sheets of lava that overflowed their natural channels and solidified to form a levee, similar to levees formed by an overflowing stream of water
Lava plain	A broad stretch of level or near level land, usually many hundreds of square kilometres in extent, underlain by a relative thin succession of lava flows, most of which are basaltic and the product of fissure eruptions.
Lava plateau	A broad, elevated tableland or flat-topped highland, usually many hundreds or thousands of square kilometres in extent, underlain by a thick succession of lava flows, most of which are tholeiitic basalts and thye product of fissure eruptions.
Lava trench	A natural surface channel in a lava flow that never had a roof, formed by the surficial draining of molten lava rather than by erosion from running water; also called lava channel.
Lava tube	A natural, hollow tunnel beneath the surface of a solidified lava flow through which the lava flow was fed; the tunnel was left empty when the molten lava drained out.
Ledge	(a) A narrow shelf or projection of rock, much longer than wide, formed on a rock wall or cliff face, as along a coast by differential wave action on softer rocks; erosion is by combined biological and chemical weathering. (b) A rocky outcrop; solid rock. (c) A shelf-like quarry exposure or natural rock outcrop.
Levee	An artificial or natural embankment built along the margin of a watercourse or an arm of the sea, to protect land from inundation or to confine streamflow to its channel.

Term	Definition
Loess bluff	A bluff composed of a thick deposit of coarse loess, formed immediately adjacent to the edges of flood plains, as along the Mississippi River valley or China. Sometimes referred to as a bluff formation (not preferred).
Loess hill	A hill composed of thick deposits of loess, as in IA, MO, NE and the Palouse Hills of WA & ID.
Longitudinal bar	Diamond or lozenge haped bar. They are the most obvious in many pebbly braided streams. They form initially by the segragation of coarse clasts as thin gravel sheets with a rhomboidal plan shape. Such bars are common in the upstream parts of some outwash fans and probably grow into higher relief longitudinals bars by a combination of vertical gravel accretion, the development of a downstream slipface and by erosion and incision by lateral channels.
Longitudinal dune	A long, narrow sand dune, usually symmetrical in cross profile, oriented parallel to the prevailing wind direction ; it is wider and steeper on the windward side but tapers to a point on the lee side. It commonly forms behind an obstacle in an area where sand is abundant and the wind is strong and constant. Such dunes can be a few meters high and up to 100 km long.
Longshore bar	A narrow, elongate, coarse-textured ridge that once rose near to, or barely above, a pluvial or glacial lake and extended generally parallel to the shore but was separated from it by an intervening trough or lagoon; both the bar and lagoon are now relict features.
Louderback	A hill or ridge composed of a lava flow remnant that caps or is exposed in a tilted fault block and bounded by a dip slope. Used as evidence of block faulting in Basin-and-Range terrain (western USA).
Lowland	(a) An informal, generic, imprecise term for low-lying land or an extensive region of low-lying land, especially near a coast and including the extended plains or country lying not far above tide level. (b) (not preferred) A generic, imprecise term for a landscape of low, comparatively level ground of a region or local area, in contrast with the adjacent higher country. (c) (not recommended – use valley, bolson, etc.) A generic term for a large valley.
Lowmoor bog	A bog that is at or only slightly above the water table, on which it depends for accumulation and preservation of peat (chiefly the remains of sedges, reeds, shrubs, and various mosses).
Main scarp	The steep surface on undisturbed ground at the upper edge of a landslide, caused by movement of displaced material away from the undisturbed ground; it is visible a part of the surface of rupture (slip surface).
Mainland cove	A subaqueous area adjacent to the mainland or a submerged mainland beach that forms a minor recess or embayment within the larger basin.
Mangrove swamp	A tropical or subtropical marine swamp formed in a silty, organic, or occasionally a coralline substratum and characterized by abundant mangrove trees along the seashore in a low area of salty or brackish water affected by daily tidal fluctuation but protected from violent wave action by reefs or land; dominated by saturated soils, commonly sulfaquents.
Marine foreland	Plain situated between a former post-glacial coastline and the present coastline. Formed through uplift or depositional processes
Marine lake	An inland body of permanently standing brackish or saline water, occupying a depression on the Earth's surface whose water level is commonly influenced by ocean tides through subterranean cavities connecting to nearby lagoons; generally of appreciable size (larger than a pond) and too deep to permit emergent vegetation to take root ompletely across the expanse of water. Such water bodies can have unique biota (e.g. sting-less jellyfish of Palau).
Marine terrace	A constructional coastal strip, sloping gently seaward, veneered by marine deposits (typically silt, sand, fine gravel).
Marsh	Periodically wet or continually flooded areas with the surface not deeply submerged. Covered dominantly with sedges, cattails, rushes, or other hydrophytic plants.
Meander	One of a series of regular freely developing sinuous curves, bends, loops, turns, or windings in the course of a stream.
Meander belt	The zone within which migration of a meandering channel occurs; the flood-plain

Term	Definition
	area included between two imaginary lines drawn tangential to the outer bends of active channel loops. Landform components of the meander-belt surface are produced by a combination of gradual (lateral and down-valley) migration of meander loops and avulsive channel shifts causing abrupt cut-offs of loop segments. Landforms flanking the sinuous stream channel include: point bars, abandoned meanders, meander scrolls, oxbow lakes, natural levees, and flood-plain splays. Meander belts may not exhibit prominent natural levee or splay forms. Flood plains of broad valleys may contain one or more abandoned meander belts in addition to the zone flanking the active stream channel.
Meander scar	A crescent-shaped, concave or linear mark on the face of a bluff or valley wall, produced by the lateral erosion of a meandering stream which impinged upon and undercut the bluff; if it's no longer adjacent to the modern stream channel it indicates an abandoned route of the stream.
Meander scroll	One of a series of long, parallel, close fitting, crescent-shaped ridges and troughs formed along the inner bank of a stream meander as the channel migrated laterally down-valley and toward the outer bank.
Meandering channel	The term "meandering" should be restricted to loops with channel length more than 1.5 to 2 times the meander wave length. Meandering stream channels commonly have cross sections with low width-to-depth ratios, cohesive (fine-grained) bank materials, and low gradient. At a given bank-full discharge, meandering streams have gentler slopes, and deeper narrower, and more stable channel cross sections than braided streams.
Medial moraine	(a) An elongate moraine carried in or upon the middle of a glacier and parallel to its sides, usually formed by the merging of adjacent and inner lateral moraines below the junction of two coalescing valley glaciers. (b) A moraine formed by glacial abrasion of a rocky protuberance near the middle of a glacier and whose debris appears at the glacier surface in the ablation area. (c) The irregular ridge left behind in the middle of a glacial valley, when the glacier on which it was formed has disappeared.
Mesa	A broad, nearly flat-topped, and usually isolated landmass bounded by steep slopes or precipitous cliffand capped by layers of resistant, nearly horizontal, rocky summit width greater than the height of bounding escarpments.
Mima mound	A term used for one of numerous low circular or oval domes composed of loose, unstratified, gravelly, silty, or sandy material. The basal diameter varies from 3 meters to more than 30 meters, and the height from 30 centimeters to about 2 meters.
Minor scarp	A steep surface on the displaced material of a landslide, produced by differential movements within the sliding mass.
Mogote	(colloquial: Caribbean Basin) An isolated, steep-sided, commonly asymmetrical hill or ridge composed of limestone, generally steeper on its leeward side (prevailing downwind side) and surrounded by nearly level to sloping coastal plain composed of marine and alluvial sediments; a type of karst tower. They range in height from a few feet (< 1 m) to over 150 ft (50 m). Most are isolated and cover small areas but some form clusters of hills or ridges rising out of the surrounding blanket deposits. Mogotes are extensive in northern Puerto Rico.
Monadnock	An isolated hill or mountain of resistant rock rising conspicuously above the general level of a lower erosion surface in a temperate climate representing an isolated remnant of a former erosion cycle in an area that has largely been beveled to its base level.
Moraine	A mound, ridge, or other accumulation of unsorted, unstratified glacial drift, predominantly till, deposited chiefly by direct action of glacier ice, in a variety of topographic landforms, that independent of control by the surface on which the drift lies. The term was probably used originally, and is still often used in European literature ,as a petrologic name for till that is being carried and deposited by a glacier; but it is now more commonly used as a geomorphologic name for a landform composed mainly of till that has been deposited by either a living or an extinct glacier.
Mound (natural)	(a) A low, rounded natural hill of unspecified origin, generally < 3 m high and,

Term	Definition
	composed of earthy material; (c) A structure built by colonial organisms (e.g. termite mound).
Mountain range	A single, large mass consisting of a succession of mountains or narrowly spaced mountain ridges, with or without peaks, closely related in position, direction, orientation, formation, and age; a component part of a mountain system.
Mountain slope	A part of a mountain between the summit and the foot.
Mountain system	A group of mountain ranges exhibiting certain unifying features, such as similarity in form, structure and alignment, and presumably originating from the same general causes; especially a series of mountain ranges belonging to an orogenic belt.
Mountain valley	(a) Any small, externally drained V-shaped depression (in cross-section) cut or deepened by a stream and floored with alluvium, or a broader, U-shaped depression modified by an alpine glacier and floored with either till or alluvium, that occurs on a mountain or within mountains. Several types of mountain valleys can be recognized based on their form and valley floor sediments (i.e., V-shaped valley, U-shaped valley).A relatively small, structural depression within a mountain range that is partly filled with alluvium and commonly drains externally to an intermontane basin, bolson, or semi-bolson.
Mountainbase	A geomorphic component of mountains consisting of the lowermost area, consisting of the strongly to slightly concave colluvial apron or wedge at the bottom of mountain slopes; composed of longtransport colluvium and slope alluvium sediment. It can extend out onto more level valley areas where it ultimately interfingers with, is buried by alluvium or is replaced by re-emergent residuum.
Mountainflank	A geomorphic component of mountains consisting of the side area of mountains, characterized by very long, complex backslopes with comparatively high slope gradients and composed of highly-diverse, colluvial sediment mantles, complex near-surface hydrology, mass movement processes and features (e.g., creep, landslides); rock outcrops or structural benches may be present. The mountainflank can be subdivided by the general location along the mountainside (i.e., upper third, middle third, or lower third mountainflank).
Mountains	A group of fundamental, three dimensional pieces or areas of mountains. In descending elevational order, the geomorphic components of a simple mountain are the mountaintop (roughly analogous to the crest or summit); mountainflank (the long slope along the sides of mountains which can be further subdivided into three portions based on the relative slope location: upper third-, middle third-, or lower third mountainflank); free face (rock outcrop); and the mountainbase (colluvium / slope alluvium apron at the bottom of the mountain).
Mountainslope	A part of a mountain between the summit and the foot
Mountaintop	A geomorphic component of mountains consisting of the uppermost, comparatively level or gently sloped area of mountains, characterized by relatively short, simple slopes composed of bare rock, residuum, or short-transport colluvial sediments. In humid environments, mountaintop soils can be quite thick and well developed.
Mud flat	A relatively level area of fine grained material (e.g. silt) along a shore (as in a sheltered estuary) or around an island, alternately covered and uncovered by the tide or covered by shallow water, and barren of vegetation.
Mud volcano	An accumulation, usually conical, ofr mud and rock ejected by volcanic gases; also, a similar accumulation formed by escaping petroliferous gases.
Mudflow	The process, associated sediments (mudflow deposit) or resultant landform characterized by a very rapid type of earthflow dominated by a sudden, downslope movement of a saturated mass of rock, soil, and mud (more than 50 % of the particles are < 2 mm), that behaves as much as a viscous fluid when moving.
Muskeg	A bog, usually a sphagnum bog, frequently with grassy tussocks (hummocks), growing in wet, poorly drained boreal regions, with deep accumulations of organic material, often in areas of permafrost; a moss-covered muck or peat bog of boreal regions.

Term	Definition
Maar	A low-relief, broad volcanic crater formed by multiple shallow explossive eruptions. It is surrounded by a crater ring, and may be filled by water
Natural bridge	(a) Any archlike rock formation created by erosive agencies and spanning a ravine or valley; an opening found where a stream broke through the narrow meander neck, as at Rainbow Bridge, Utah. (b) In a limestone terrane, the remnant of the roof of an underground cave or tunnel that has collapsed.
Natural levee	A long, broad low ridge or embankment of sand and coarse silt, built by a stream on its flood plain and along both sides of its channel, especially in time of flood when water overflowing the normal banks is forced to deposit the coarsest part of its load. It has a gentle slope away from the river and toward the surrounding floodplain, and its highest elevation is closest to the river bank.
Neck	A vertical, pipelike intrussion that represents a former volcanic vent. The term is usually applied to the form as an erosional remnant.
Net (sorted and unsorted)	(Not preferred) Refer to patterned ground.
Nivation hollow	A shallow, non-cliffed depression or hollow on a mountain side permanently or intermittently occupied by a snow bank or snow patch and produced by nivation. If the snow completely melts each summer the hollow is deepened; otherwise not; may be a cirque precursor if further enlarged and deepened by alpine glaciation.
Nonsorted circle	A type of patterned ground whose mesh (shape) is dominantly circular and has a nonsorted appearance due to the absence of a boarder of coarse fragments. Vegetation characteristically outlines the pattern by forming a bordering ridge. Diameters commonly range from 0.5 to 3 m. Nonsorted circles include mud boils, earth hummocks, turf hummocks, and frost boils. Nonsorted circles have various origins. Some, such as mud and earth hummocks and frost boils, involve cryoturbation activity and differential heave of frost-susceptible materials. Others, such as mud boils, involve hydraulic pressures and diapir-like displacement of water-saturated sediments.
Nose slope	A geomorphic component of hills consisting of the projecting end (laterally convex area) of a hillside, resulting in predominantly divergent overland water flow (e.g., sheet wash); contour lines generally form convex curves. Nose slopes are dominated by colluvium and slope wash sediments (e.g., slope alluvium). Slope complexity (downslope shape) can range from simple to complex. Nose slopes are comparatively drier portions of hillslopes and tend to have thinner colluvial sediments and profiles.
Notch	(a) (colloquial - northeast USA) A narrow passageway, or short defile between mountains; a deep, close pass. (b) A breached opening in the rim of a volcanic crater.
Nunatak	An isolated hill, knob, ridge, or peak of bedrock that projects prominently above the surface of a glacier and is completely surrounded by glacier ice.
Ocean	The continuous salt-water body that surrounds the continents and fills the Earth's great depressions; also, one of its major geographic divisions.
Open depression	A generic name for any enclosed or low area that has a surface drainage outlet whereby surface water can leave the enclosure; an area of lower ground indicated on a opographic map by contour lines forming an incomplete loop or basin indicating at least one surface exit.
Outwash delta	A relict (inactive) delta composed of glaciofluvial sediments formed where a sediment laden outwash river emptied into an open lake, commonly a proglacial lake. Sediment attributes include very gently dipping topset beds (coarser textures) and steeply dipping foreset beds (finer textures).
Outwash fan	A fan-shaped accumulation of outwash deposited by meltwater streams in front of the end or recessional moraine of a glacier. Coalescing outwash fans form an outwash plain.
Outwash plain	An extensive lowland area of coarse textured, glaciofluvial material. An outwash plain is commonly smooth; where pitted, due to melt-out of incorporated ice masses (pitted outwash plain), it is generally low in relief and largely retains its original gradient.
Outwash terrace	A flat-topped bank of outwash with an abrupt outer face (scarp or riser) extending

Term	Definition
	along a valley downstream from an outwash plain or terminal moraine; a valley train deposit.
Overflow stream channel	A watercourse that is generally dry but conducts flood waters that have overflowed the banks of a river, commonly from large storms, annual meltwater, or glacial meltwaters.
Oxbow lake	The crescent-shaped, often ephemeral body of standing water situated by the side of a stream in the abandoned channel (oxbow) of a meander after the stream formed a neck cutoff and the ends of the original bend were silted up.
Paha	(colloquial: Midwestern USA) Commonly a low, elongated, rounded ridge or hill cored by an erosional remnant of drift, rock, or windblown sand, silt, or clay and capped with a thick cover (e.g. up to 10 m) of loess; found especially in northeast Iowa. Height varies between 10 and 30 m.
Pahoehoe lava flow	A type of basaltic lava flow with a characteristically smooth, billowy or rope-like surface.
Paleoterrace	An erosional remnant of a terrace which retains the surface form and alluvial deposits of its origin but was not emplaced by, and commonly does not grade to a present-day stream or drainage network.
Palsa	An elliptical dome-like permafrost mound containing alternating layers of ice lenses and peat or mineral soil, commonly 3-10 m high and 2-25 m long, occurring in subarctic bogs of the tundra and often surrounded by water; pl. palsen.
Parabolic dune	A sand dune with a long, scoop-shaped form, convex in the downwind direction so that its horns point upwind, whose ground plan, when perfectly developed, approximates the form of a parabola.
Parallel drainage pattern	A drainage pattern in which the streams and their tributaries are regularly spaced and flow parallel or subparallel to one another and tributaries characteristically join the mainstream at approximately the same angle, over a considerable area. It is indicative of a region having a pronounced, uniform slope and a homogeneous lithology and rock structure, such as young coastal plains and large basalt flows.
Parna dune	A dune largely composed of silt and sand-sized aggregates of clay; sometimes called a clay dune or lunette.
Partial ballena	(not preferred) refer to ballena
Patterned ground	A general term for any ground surface exhibiting a discernibly ordered, more-or-less symmetrical, morphological pattern of ground and, where present, vegetation. Patterned ground is characteristic of, but not confined to, permafrost regions or areas subjected to intense frost action; it also occurs in tropical, subtropical, and temperate areas. Patterned ground is classified by type of pattern and presence or absence of sorting and includes nonsorted and sorted circles, net, polygons, steps and stripes, garlands, and solifluction features. In permafrost regions, the most common macroform is the ice-wedge polygon and a common microform is the nonsorted circle. Stone polygons generally form on slopes of less than 8 percent, while garlands and stripes occur on slopes of 8 to 15 percent and more than 15 percent, respectively.
Pavement karst	Areas of bare limestone, usually sculpted by solution erosion into karren of various types and where soils have been stripped off, commonly by glaciation in alpine areas (e.g. Rocky Mountains – USA) and high latitudes, and by water erosion in arid karst areas.
Peak	Sharp or rugged upward extension of a ridge chain, usually at the junction of two or more ridges; the prominent highest point of a summit area.
Peat plateau	A generally flat-topped expanse of peat, elevated above the general surface of a peatland, and containing segregated ice that may or may not extend downward into the underlying mineral soil. Controversy exists as to whether peat plateaus and palsen are morphological variations of the same feature.
Pediment	A gently sloping erosional surface developed at the foot of a receding hill or mountain slope, commonly with a slightly concave-upward profile, that cross-cuts rock or sediment strata that extend beneath adjacent uplands. The erosion surface may be essentially bare bedrock (i.e. rock pediment), or it may be thinly mantled (e.g. 1 to 3 m) with debris (i.e. pediment) such as colluvium, pedisediment, or alluvium that is ultimately in transit from an upland front to basin

Term	Definition
	or valley lowland. In hill-footslope terrain the debris mantle (over an erosional contact) is designated "pedisediment." The term has been used in several geomorphic contexts: Pediments may be classed with respect to (a) landscape positions (e.g. intermontane basin piedmont = apron pediment, or valley-border footslope surfaces (= terrace pediment); Cooke and Warren, 1973); (b) type of material eroded (e.g. bedrock = rock pediment, or regolith = pediment); or (c) combinations of the above.
Peninsula	(a) An elongated body or stretch of land nearly surrounded by water (e.g., on three sides) and connected with a larger tract of land area, usually by a neck or an isthmus. (b) A relatively large tract of land jutting out into the water, with or without a well-defined isthmus; e.g., the Italian peninsula.
Perennial stream	A stream or reach of a stream that flows continuously throughout the year and whose surface is generally lower than the water table adjacent to the region adjoining the stream.
Permafrost	Ground, soil, or rock that remains at or below 0o C for at least two years. It is defined on the basis of temperature and is not necessarily frozen.
Piedmont	(adjective) Lying or formed at the base of a mountain or mountain range; e.g., a piedmont terrace or a piedmont pediment. (noun) An area, plain, slope, glacier, or other feature at the base of a mountain; e.g., a foothill or a bajada. In the United States, the Piedmont (noun) is a low plateau extending from New Jersey to Alabama and lying east of the Appalachian Mountains.
Piedmont slope	(colloquial – western USA) The dominant gentle slope at the foot of a mountain; generally used in terms of intermontane-basin terrain in arid to subhumid regions. Main components include: (a) An erosional surface on bedrock adjacent to the receding mountain front (pediment, rock pediment); (b) A constructional surface comprising individual alluvial fans and interfan valleys, also near the mountain front; and (c) A distal complex of coalescent fans (bajada), and alluvial slopes without fan form. Piedmont slopes grade to basin-floor depressions with alluvial and temporary lake plains or to surfaces associated with through drainage (e.g., axial streams).
Pillow lava flow	A lava flow or body displaying pillow structure and considered to have formed in a subaqueous environment (underwater); usually basaltic or andesitic in composition.
Pimple mound	(colloquial: Gulf Coast U.S.A.) Low, flattened, approximately circular or elliptical features composed of sandy loam that is coarser than, and distinct from, the surrounding soil; the basal diameter ranges from 3 m to more than 30 m, and the height from 30 cm to more than 2 m.
Pingo	A large frost mound; especially a relatively large conical mound of soil-covered ice (commonly 30 to 50 meters high and up to 400 meters in diameter) raised in part by hydrostatic pressure within and below the permafrost of Arctic regions, and of more than 1 year's duration.
Pinnacle	A tall, slender, tapering tower or spire-shaped pillar of rock, either isolated, as on steep slopes or cliffs formed in karst or other massive rocks, or at the summit of a hill or mountain.
Pinnate drainage pattern	A variation of the dendritic drainage pattern in which the main stream receives many closely spaced, subparallel tributaries that join it at slightly acute angles upstream, resembling in plan a feather. They typically form on steep slopes with soils that have a high silt content; such as loess landscapes or fine-textured flood plains.
Pitted outwash plain	An outwash plain marked by many irregular depressions such as kettles, shallow pits, and potholes which formed by melting of incorporated ice masses; much of the gradient and internal structures of the original plain remain intact; many are found in WI, MN, MI, and IN.
Pitted outwash terrace	A relict glaciofluvial terrace that retains its original attitude, composed of undistorted outwash sediments and depositional structures and whose surface is pock-marked with numerous potholes or kettle depressions.
Plain	A general term referring to any flat, lowland area, large or small, at a low elevation. Specifically, any extensive region of comparatively smooth and level

Term	Definition
	gently undulating land. A plain has few or no prominent hills or valleys but sometimes has considerable slope, and usually occurs at low elevation relative to surrounding areas. Where dissected, remnants of a plain can form the local uplands. A plain may be forested or bare of trees and may be formed by deposition or erosion.
Plateau	A comparatively flat area of great extent and elevation; specifically an extensive land region considerably elevated (more than 100 meters) above adjacent lower-lying terrain, and is commonly limited on at least one side by an abrupt descent, has a flat or nearly level surface. A comparatively large part of a plateau surface is near summit level
Playa	The usually dry and nearly level lake plain that occupies the lowest parts of closed depressions, such as those occurring on intermontane basin floors. Temporary flooding occurs primarily in response to precipitation-runoff events. Playa deposits are fine grained and may or may not have high water table and saline conditions.
Playa dune	(colloquial – Southern High Plains) A linear or curvilinear ridge of windblown, granular material (generally sand or parna) removed from the adjacent basin by wind erosion (deflation), and deposited on the leeward (prevailing downwind) margin of a playa, playa basin, or salina basin. The dune may be barren or vegetated.
Playa floor	(colloquial – Southern High Plains) The lowest extensive, flat to slightly concave surface within a playa basin, consisting of a dry lake bed or lake plain underlain by stratified clay, silt or sand, and commonly by soluble salts.
Playa lake	A shallow, intermittent lake in a arid or semi-arid region, covering or occupying a playa in the wet season but drying up in summer; an ephemeral lake that upon evaporation leaves or forms a playa.
Playa rim	(colloquial – Southern High Plains) The convex, upper margin (shoulder) of a playa basin where the playa slope intersects the surrounding terrain.
Playa slope	(colloquial – Southern High Plains) The generally concave to slightly convex area within a playa basin that lies between the relatively level playa floor below (or playa step, if present) and the convex playa rim above. Overland flow is typically parallel down slope.
Playa step	(colloquial – Southern High Plains) The relatively level or gently inclined “terrace-like” bench or toeslope within a large playa basin flanking and topographically higher than the playa floor and below the playa slope; a bench or step-like surface within a playa basin that breaks the continuity of the playa slope and modified by erosion and/or deposition. Temporary ponding may occur in response to precipitation / runoff events.
Playette	A very small, playa-like, shallow, closed depression typically with a salt-encrusted surface, little or no vegetation in semi-arid to arid climates and infrequently subject to ponding from precipitation events; commonly lacks the component parts of a playa except for a small playa floor.
Plug	A consolidated crater-filling of lava, the surrounding material of which has been largely removed by erosion leaving an isolated hill or knob.
Plug dome	A volcanic dome characterized by an upheaved, consolidated conduit filling.
Pluvial lake	A lake formed in a period of exceptionally heavy rainfall; a lake formed in the Pleistocene Epoch during a time of glacial advance, and now either extinct (relict) or existing as a remnant (lake); e.g.,Lake Bonneville.
Pocosin	(colloquial: southeastern U.S.A.) A large wet area on broad, commonly a swamp, which occurs on nearly level interfluves in the Atlantic coastal plain with distinctive, native vegetation relative to adjacent areas. Soils may be either mineral or organic. A Native American term for "swamp on a hill."
Point bar	One of a series of low, arcuate ridges of sand and gravel developed on the inside of a growing meander by the slow addition of individual accretions accompanying migration of the channel toward the outer bank.
Polje/Interior valley	A large, flat-floored closed depression in a karst area whose drainage is ultimately subsurface and its floor is commonly covered by alluvium. Some interior valleys may become ephemeral lakes during periods of heavy rainfall, when sinking streams that drain them cannot manage the runoff; also called polje (not

Term	Definition
	preferred).
Polygon	A type of patterned ground consisting of a closed, roughly equidimensional figure bounded by more or less straight sides; some sides may be irregular. Refer to patterned ground.
Pond (natural)	A natural body of standing fresh water occupying a small surface depression, usually smaller than a lake and larger than a pool.
Pool (natural)	A small, natural body of standing water, usually fresh; e.g. a stagnant body of water in a marsh, or a transient puddle in a depression following a rain.
Pothole	(a) A type of small pit or closed depression (1 to 15 meters deep), generally circular or elliptical, occurring in an outwash plain, a recessional moraine, or a till plain. (b) A shallow depression, generally less than 10 hectares in area, occurring on disintegration moraines and commonly containing an intermittent or seasonal pond or marsh. (c) (not preferred) A generic, imprecise term for any pot-shaped pit or hole.
Pressure ridge (ice)	A rugged, irregular wall of broken floating ice buckled upward by the lateral pressure of wind or current forcing or squeezing one floe against another, or against a shore; it may extend for kilometers in length and up to 30 m in height. Along shores they are lower (< 10 m tall) and contribute to the temporary or permanent formation of a beach berm or a rim of boulders and stones.
Pressure ridge (volcanic)	An elongate uplift of the congealing crust of a lava flow, probably due to the pressure of the underlying, still-flowing lava; commonly < 5 m in height (but range up to 15 m) and < 100 m length (but can exceed 500 m).
Proglacial lake (ice)	A type of glacial lake which formed just beyond the margin of an advancing or retreating glacier; generally in direct contact with the ice.
Proglacial lake (relict)	Remnant features of a glacial lake that is now extinct which formed just beyond the margin of an advancing or retreating glacier; generally in direct contact with the ice.
Pyroclastic flow	A fast density current of pyroclastic material, usually very hot, composed of a mixture of gasses and a variety of pyroclastic particles (ash, pumice, scoria, lava fragments, etc.); produced by the explosive disintegration of viscous lava in a volcanic crater or by the explosive emission of gas-charged ash from a fissure and which tends to follow topographic lows (e.g. valleys) as it moves; used in a more general sense than ash flow.
Pyroclastic surge	A low density, dilute, turbulent pyroclastic flow, usually very hot, composed of a generally unsorted mixture of gases, ash, pumice and dense rock fragments that travels across the ground at high speed and less constrained by topography than a pyroclastic flow; several types of pyroclastic surges can be specified (e.g. base surge, ash-cloud-surge).
Radial drainage pattern	A drainage pattern in which consequent streams radiate or diverge outward, like the spokes of a wheel from a high central area.; a major collector stream is usually found in a curvilinear alignment around the bottom of the elevated topographic feature. It is best developed on the slopes of a young domal structure, a volcanic cone, or isolated hills (erosional remnant).
Raised beach	An ancient (relict) beach occurring above the present shoreline and separated from the present beach, having been elevated above the high-water mark either by local crustal movements (uplift) or by lowering of sea or lake level, and which may be bounded by inland cliffs.
Raised bog	An area of acid, peaty soil especially that developed from moss, in which the center is higher than the margins. Compare - pocosin, Carolina Bay, moss peat.
Rambla	A dry ravine, or the dry bed of an ephemeral stream.
Ravine	A small stream channel; narrow, steep-sided, commonly V-shaped in cross section and larger than a gully, cut in unconsolidated materials. General synonym (not preferred) -gulch.
Recessional moraine	An end or lateral moraine built during a temporary but significant pause in the final retreat of a glacier. Also, a moraine built during a slight or minor readvance of the ice front during a period of general recession.
Rectangular drainage pattern	A drainage pattern in which the tributaries join the main streams at rightangles, and exhibit sections of approximately the same length which form rectangular

Term	Definition
	shapes; it is indicative of streams following prominent bedrock fault, joint, or foliation systems that break the rocks into rectangular blocks. It is more irregular than the trellis drainage pattern, as the side streams are not perfectly parallel and not necessarily as conspicuously elongated, and secondary tributaries need not be present. The stronger or more harsh the pattern, the thinner the soil cover. These patterns commonly form in slate, schist, and gneiss, in resistive sandstone in arid climates, or in sandstone in humid climates if little soil has developed.
Reef	(a) A ridge-like or mound-like structure, layered or massive, built by sedentary calcareous organisms, especially corals, and consisting mostly of their remains; it is wave-esistant and stands above the surrounding contemporaneously deposited sediment. Reefs can also include a mass or ridge of rocks, especially coral and sometimes sand, ravel, or shells, rising above the surrounding estuary, sea or lake bottom to or nearly to the surface.
Relict	Pertaining to surface landscape features e.g., landforms, geomorphic surfaces, and paleosols that have never been buried and yet are predominantly products of past environments.
Relict-tidal inlet	A channel remnant of a former tidal inlet. The channel was cutoff or abandoned by infilling from migrating shore sediments.
Reworked lake plain	The bottom of a shallow, extinct glacial lake composed of thin (e.g., < 2 m thick), fine-textured, reworked lacustrine sediments that overlie outwash or till; original lacustrine sediments have been subsequently redistributed primarily by wave action (eroded and / or moved a short distance). A distinctive lake plain topography is not always present. It may include subdued, till-capped topographic highs, ringed by shores or strandlines that were once emergent islands.
Rib	A small, high angle, tertiary spur ridge or mini-interfluve that is a constituent part of rib & groove topography; (slopes generally 20 - 90 %,); common on the mid and lower hillslopes of well dissected uplands.
Rib and groove topography	A local scale topography composed of repeating, small, high-angle (slopes generally 20 - 90 %), tertiary spur ridges or mini-interfluves (ribs) separated by small, natural, narrow drainageways (grooves); the overall effect is a corrugated transverse surface, common on the mid and lower slopes of well dissected uplands in semi-arid to humid environments (e.g. Basin and Range, Ozarks, etc.). Micro-elevational differences generally range from < 3 to < 15 m. SW
Ridge	A long, narrow elevation of the land surface, usually sharp crested with steep sides and forming an extended upland between valleys. The term is used in areas of both hill and mountain relief.
Rill	A small, high angle, tertiary spur ridge or mini-interfluve that is a constituent part of rib & groove topography; (slopes generally 20 - 90 %,); common on the mid and lower hillslopes of well dissected uplands.
Rim	The border, margin, edge, or face of a landform, such as the curved brim surrounding the top part of a crater or caldera; specifically the rimrock of a plateau or canyon.
River valley	An elongate depression of the Earth's surface carved by a river during the course of its development.
Roche moutonnée	A small elongate protruding knob or hillock of bedrock, so sculptured by a large glacier as to have its long axis oriented in the direction of ice movement, an upstream (stoss or scour) side that is gently inclined, smoothly rounded, and striated, and a downstream (lee or pluck) side that is steep and rough. It is usually a few meters in height, length, and breadth.
Rock fall	The process, associated sediments (rockfall deposit) or resultant landform characterized by a very rapid type of fall dominated by downslope movement of detached rock bodies which fall freely through the air or by leaps and bounds (lacks an underlying slip face); also spelled rock fall.
Rock glacier	A mass of poorly sorted angular boulders and fine material, with interstitial ice a meter or so below the surface (ice-cemented) or containing a buried ice glacier (ice-cored). It occurs in a permafrost area, and is derived from a cirque wall or other steep cliff. Rock glaciers have the general appearance and slow movement of small valley glaciers, ranging from a few hundred meters to several kilometers

Term	Definition
	in length, and having a distal area marked by a series of transverse, arcuate ridges.
Rock pediment	An erosion surface of low relief, cut directly into and across bedrock and composed of either bare rock or thinly veneered pedisediment or residuum (e.g. < 1.5 m) over bedrock; it occurs along the flanks of mountain fronts, or at the base of mountains or high hills. Its surface grades to the backwearing mountain slopes or hillslopes above, and generally grades down to and merges with a lower-lying alluvial plain, piedmont slope or valley floor below. (b) The track of bare rock or furrowed earth left by a slide. (c) The mass of material moved in or deposited by a slide.
Rock spread	The process, associated sediments (rock spread deposit) or resultant landforms characterized by a very rapid type of spread dominated by lateral movement in a rock mass resulting from liquefaction or plastic flow of underlying materials that may be extruded out between intact units; rock bodies predominate.
Rock topple	The process, associated sediments (rock topple deposit) or resultant landform characterized by a localized, very rapid type of fall in which large blocks of rock material literally fall over, rotating outward over a low pivot point; rock bodies predominate (little fine earth). Portions of the original material may remain intact, although reoriented, within the resulting deposit.
Rockfall avalanche	The process, associated sediments (rockfall avalanche deposit) or resultant landform characterized by an extremely rapid, large type of rock-fragment flow (a type of landslide) that starts as a rockfall but turns into a flow and characteristically deposits rock-dominated debris long distances from the failure face (such as 10 – 20 times the fall height); occurs only when huge rockfalls and rockslides involving millions of metric tons of material attain extremely rapid speeds; most common in a rugged mountainous area; ex. the 1903 Franks, Alberta, Canada avalanche. Sometimes loosely referred to as a long run-out landslide.
Rotational debris slide	The process, associated sediments (rotational debris slide deposit) or resultant landform characterized by an extremely slow to moderately rapid type of slide, composed of comparatively dry and largely unconsolidated earthy material, portions of which remain largely intact and in which movement occurs along a well-defined, concave shear surface and resulting in a backward rotation of the displaced mass; sediments have substantial proportions of both fine earth and coarse fragments. The landform may be single, successive (repeated up and down slope), or multiple (as the number of slide components increase).
Rotational earth slide	The process, associated sediments (rotational earth slide deposit) or resultant landform characterized by an extremely slow to moderately rapid type of slide, composed of comparatively dry and largely unconsolidated earthy material, portions of which remain largely intact and in which movement occurs along a well-defined, concave shear surface and resulting in a backward rotation of the displaced mass; sediments predominantly fine earth (< 2 mm). The landform may be single, successive (repeated up and down slope), or multiple (as the number of slide components increase).
Rotational landslide	(not preferred) use rotational slide.
Rotational rock slide	The process, associated sediments (rotational rock slide deposit) or resultant landform characterized by an extremely slow to moderately rapid type of slide, composed of comparatively dry and largely consolidated rock bodies, portions of which remain largely intact but reoriented, and in which movement occurs along a well-defined, concave shear surface and resulting in a backward rotation of the displaced mass. The landform may be single, successive (repeated up and down slope), or multiple (as the number of slide components increase).
Rotational slide	The process, associated sediments (rotational landslide deposit) or resultant landforms characterized by an extremely slow to moderately rapid type of slide, composed of comparatively dry and largely soil-rock materials, portions of which remain largely intact and in which movement occurs along a well-defined, concave shear surface and resulting in a backward rotation of the displaced mass. The landform may be single, successive (repeated up and down slope), or multiple (as the number of slide components increase).

Term	Definition
Sabkha	(a) A supratidal environment of sedimentation, formed under arid to semiarid conditions on restricted coastal plains just above the normal high-tide level (a saline marsh). It is the gradational zone betwen high-tide level (a saline marine marsh). Sabkhas are characterized by evaporite-saline minerlas, tidal flood, and eolian deposits, and are found on many modern coastlines. (b) Any flat area, coastal or interior, where, through deflation and evaporation, saline minerals cristalize near ot the surface.
Saddle	A low point on a ridge or interfluve, generally a divide (pass, col) between the heads of streams flowing in opposite directions.
Sag	A small, partially or completely closed depression formed by movement along a strike-slip fault, or by mass movement (i.e., landslide) that may or may not temporarily pond water from impounded drainage or surface runoff. For example, a closed depression formed between a scarp or headwall and an adjacent rotated slump block of a landslide.
Sag pond	A small, permanent body of water in a semi-closed or closed depression formed by movement along a strike-slip fault or by mass movement (i.e., landslide) that ponds water from impounded drainage or surface runoff. Also spelled sagpond.
Salt marsh	Flat, poorly drained area that is subject to periodic or occasional overflow by salt water, containing water that is brackish to strongly saline, and usually covered with a thick mat of grassy halophytic plants; e.g., a coastal marsh periodically flooded by the sea, or an inland marsh, (or salina) in an arid region and subject to intermittent overflow by salty water.
Salt pond	A large or small body of salt water in a marsh or swamp along the seacoast.
Sand boil	An accumulation of sand commonly in the form of a low mound, produced by the expulsion of liquefied sand to the ground surface; sometimes called sand volcanoes (not preferred). Examples are found on top of some landslide deposits (i.e. spreads) or on the upper surface of highly contorted layers of laminated sediments.
Sand flow	a) A flow of wet sand, as along banks of noncohesive clean sand that is subject to scour and to repeated fluctuations in pore-water pressure due to rise and fall of the tide. b) A flow of loose, dry sand, as along the slip face of a sand dune; typically a microfeature.
Sand plain	A sand-covered plain, which may originate by deflation of sand dunes,and whose lower limit of erosion is governed by the water table. Also spelled sandplain.
Sand ramp	A sand sheet blown up onto the lower slopes of a bedrock hill or mountain and forming an inclined plane, sometimes filling small mountain-side valleys and even crossing low passes.
Sand sheet	A large, irregularly shaped, commonly thin, surficial mantle of eolian sand, lacking the discernible slip faces that are common on dunes.
Sandhills	A region of semi-stabilized sand dunes or sandy hills, either covered with vegetation or bare, as in north-central Nebraska and the midlands of the Carolinas.
Scarp	An escarpment, cliff, or steep slope of some extent along the margin of a plateau, mesa, terrace, or structural bench. A scarp may be of any height.
Scarp slope	The relatively steeper face of a cuesta, facing in a direction opposite to the dip of the strata.
Scree	A collective term for an accumulation of coarse rock debris or a sheet of coarse debris mantling a slope. Scree is not a synonym of talus, as scree includes loose, coarse fragment material on slopes without cliffs.
Scree slope	A portion of a hillside or mountainslope mantled by scree and lacking an up-slope rockfall source (i.e. cliff)
Sea	a) A large inland body of salt water (e.g. the Sultan Sea, CA). b) A geographic subdivision of an ocean (e.g. the South China Sea).
Sea cliff	A significant vertical, or near vertical, rock exposure formed by wave action
Seif dune	A large, sharp-crested, elongated, longitudinal (linear) dune or chain of sand dunes, oriented parallel, rather than transverse (perpendicular), to the prevailing wind. If unmodified, the crest, in profile, commonly consists of a succession of curved slip faces produced by strong, but infrequent cross winds. A seif dune may

Term	Definition
	be as much as 200 m high and from 400 m to more than 100 km long.
Semi-bolson	(colloquial: western USA) A wide desert basin or valley that is drained by an intermittent stream, an externally drained (open) intermontane basin.
Semi-open depression	A topographically enclosed basin that generally functions as a closed depression and lacks a defined exit channel. Surface water loss may occur via overland flow through a topographic low area or gap in response to large storm events. Semi-open depressions commonly contain small lakes, ponds, or wet meadows dominated by hydric soils (e.g. in karst valleys, or in low areas on marine terraces with < 1 % slopes)
Shield volcano	A volcano having the shape of a very broad, gently sloping dome, built by flows of very fluid basaltic lava or rhiolitic ash flows.
Shoal	(a) A relatively shallow place in a stream, lake, sea, or other body of water; a shallows. (b) A natural, subaqueous ridge, bank, or bar consisting of, or covered by, sand or other unconsolidated material, rising from the bed of a body of water (e.g. estuarine floor) to near the surface. It may be exposed at low water. (c) Relict: A surficial ridge, bank, or bar consisting of sand or other subaqueous deposit that has become permanently exposed by the retreat or lowering of a proglacial lake or other body of water.
Shore	The narrow strip of land immediately bordering any body of water, esp. the sea or a large lake; specifically the zone over which the ground is alternately exposed and covered by tides or waves, or the zone between high water and low water.
Shore complex	Generally a narrow, elongate area that parallels a coastline, commonly cutting across diverse inland landforms, and dominated by landforms derived from active coastal processes which give rise to beach ridges, washover fans, beaches, dunes, wave-cut platforms, barrier islands, cliffs, etc.
Shoreline	The intersection of a specified plane of water with the beach; it migrates with changes of the tide or of the water level.
Shoulder	A bench on the side of a glaciated valley, occuring at the marked change of slope where the steep side of the inner, glaciated valley, meets the much gentle slope above the level of glaciation
Shrub-coppice dune	A small, streamlined dune that forms around brush and clump vegetation.
Sinkhole karst	A landscape dominated by subsurface drainage and sinkholes (dolines) that range widely in sizes and density; the most common type of karst in upland areas of temperate regions (e.g. Highland Rim of TN, northern FL, southwestern MO, etc.); also called doline karst (not preferred).
Sinkhole/Doline	A closed, circular or elliptical depression, commonly funnel-shaped, characterized by subsurface drainage and formed either by dissolution of the surface of underlying bedrock (e.g., limestone, gypsum, salt) (solution sinkhole) or by collapse of underlying caves within bedrock (collapse sinkhole); diameters range from a few meters to as much as 1000 m. Complexes of sinkholes in carbonate-rock terrain are the main components of karst topography. Synonym (not preferred) - doline.
Slick rock	(colloquial: southwestern U.S.A.) A barren, highly smoothed and subrounded bedrock pavement with considerable, irregular topography sculpted primarily by wind in an arid climate; a type of rock outcrop common on the top of massive sandstone bedrock (e.g. Navajo, Windgate, or Kayenta Formations), especially on summits of ridges and near the leading edge of plateaus, mesas and cuestas.
Slide	(a) - A category of mass movement processes, associated sediments (slide deposit) or resultant landforms (e.g., rotational slide, translational slide, and snowslide) characterized by a failure of earth, snow, or rock under shear stress along one or several surfaces that are either visible or may reasonably be inferred. The moving mass may or may not be greatly deformed, and movement may be rotational (rotational slide) or planar (translational slide). A slide can result from lateral erosion, lateral pressure, weight of overlying material, accumulation of moisture, earthquakes, expansion owing to freeze-thaw of water in cracks, regional tilting, undermining, fire, and human agencies.
Slip face	The steeply sloping surface on the lee side of a dune, standing at or near the angle of repose of loose sand, and advancing downwind by a succession of slides

Term	Definition
	wherever that angle is exceeded.
Slip surface	A landslide displacement surface, often slickensided and striated, or brecciated, and subplanar. It is best exhibited in argillaceous materials and in those materials which are highly susceptible to clay alteration when granulated; also called shear surface (not preferred).
Slope	The inclination of the land surface from the horizontal. Percent slope is the vertical distance divided by the horizontal distance, then multiplied by 100.
Slot canyon	A long, narrow, deep and tortuous channel or drainageway with sheer rock walls eroded into sandstone or other sedimentary rocks, especially in the semi-arid western USA (e.g. Colorado Plateau); subject to flash flood events; depth to width ratios exceed 10:1 over most of its length and can approach 100:1; commonly containing unique ecological communities distinct from the adjacent, drier uplands.
Slough	(a) A small marsh, especially a marshy area lying in a local, shallow, closed depression on a piece of dry land, as on the prairie of the Midwestern U.S.A. (b) A term used, especially in the Mississippi Valley, for a creek or sluggish body of water in a tidal flat, flood plain, or coastal marshland. (c) A sluggish channel of water, such as a side channel of a river, in which water flows slowly through low, swampy ground, as along the Columbia River, or a section of an abandoned river channel which may contain stagnant water and occurs in a flood plain or delta. (d) (not preferred) An area of soft, miry, muddy or waterlogged ground, a place of deep mud.
Slump	(a) (not preferred- refer to rotational slide) A generic, obsolete term for various types of landslides, especially rotational landslide; the process, associated sediments, or resultant landform characterized by a slide involving a shearing and rotary movement of a generally independent mass of rock or earth along a curved slip surface (concave upward) and about an axis parallel to the slope from which it descends, and by backward tilting of the mass with respect to that slope so that the slump surface often exhibits a reversed slope facing uphill. Compare - rotational slide, slide, landslide. (b) (not recommended) refer to rotational slide. An informal term for the landform or mass of material slipped down during, or produced by a landslide.
Slump block	A mass of material torn away as a coherent unit during a landslide; a largely intact but displaced and commonly reoriented body of rock or soil.
Snowfield	a) A broad expanse of terrain covered with snow, relatively smooth and uniform in appearance, occurring usually at high latitudes or in mountainous regions above the snowline and persisting throughout year. b) A region of permanent snow cover, as at the head of a glacier; the accumulation area of a glacier.
Soil fall	The process, associated sediments (soil fall deposit) or resultant landform characterized by a rapid type of fall involving the relatively free, downslope movement or collapse of detached, unconsolidated soil material which falls freely through the air (lacks an underlying slip face); sediments predominantly fine earth (< 2 mm); common along undercut stream banks. Also called earth fall, and (not recommended) debris fall.
Solifluction lobe	An isolated tongue-shaped feature up to 25 m wide and 150 m or more long, formed by rapid solifluction on certain sections of a slope showing variations in gradient. This feature commonly has a steep (e.g. 15o - 60o) front and a relatively smooth upper surface.
Solifluction sheet	A broad deposit of nonsorted, water-saturated, locally derived material that is moving or has moved downslope, en masse. Stripes are commonly associated with solifluction sheets.
Solifluction terrace	A low step with a straight or lobate front, the latter reflecting local differences in rate of flow. A solifluction terrace may have bare mineral soil on the upslope part and 'folded under' organic matter in both the seasonally thawed and the frozen soil.
Solution chimney	Small diameter (e.g. 1-5 m), irregular, hollow, vertical shaft 5-10+ m deep on karst landscapes, typically covered with a thin layer of soil or plant debris that can collapse and expose the shaft to the surface; represents a significant safety hazard. Locally called “stove-pipe sinkholes in Florida (not recommended).

Term	Definition
Solution corridor	solution corridor – A straight, open trench about 3 to 10 m wide in a karst area, formed by vertical and lateral solution zones developed along bedrock fractures; also called (not preferred) bogaz, zanjon (Puerto Rico).
Solution fissure	One of a series of vertical open cracks commonly < 0.5 m wide dissolved along joints or fractures, separating limestone pavement (pavement karst) into blocks (clints); also called kluftkarren (not preferred).
Solution pipe	A subsurface, vertical, cylindrical or cone-shaped hole, formed by dissolution in soluble bedrock (e.g. limestone) and often without surface expression, that is filled with detrital material (e.g. soil) and which serves as a bypass route for internal water flow.
Solution platform	A broad, nearly horizontal intertidal surface (modern or relict) formed across carbonate rocks, produced primarily by solution with contributions by intertidal weathering and biological erosion and deposition, not by abrasion.
Solution sinkhole	The most common type of sinkhole, caused by dissolution that forms fissures or a chimney and a depression in the bedrock surface which grows when closely spaced fissures underneath it enlarge and coalesce.
Sorted (and unsorted) polygon	Refer to patterned ground.
Sorted circle	A type of patterned ground whose mesh (shape) is largely circular and has a sorted appearance commonly due to a border of coarse fragments surrounding finer material, occurring either singly or in groups. Diameters range from a few centimeters to more than 10 meters. The coarse fragment border may be 35 cm high and 8 to 12 cm wide.
Sound	a) A relatively long, narrow waterway connecting two larger bodies of water (as a sea or lake with the ocean or another sea) or two parts of the same water body, or an arm of the sea forming a channel between the mainland and an island (e.g. Puget Sound, WA); it is generally wider and more extensive than a strait [coast]. b) A long, large, rather broad inlet of the ocean, generally extending parallel to the coast (e.g. Long Island Sound, NY). C) A lagoon along the southeast coast of the US (e.g. Pamlico Sound, NC). d) A long bay or arm of a lake; a stretch of water between the mainland and a long island in a lake.
Spatter cone	A small, steep-sided cone (e.g., 3 – 15 m high, or more) built up on a lava flow, usually pahoehoe, composed of clots of lava ejected with escaping gases from a vent or fissure which spatters and congeals as it hits the ground to form a small cone; rougher lava clots than a spiracle.
Spiracle	A small tubular opening or chimney formed by fluid lava congealing and mounding around a fumarolic vent in a basaltic lava flow, usually about 1 m in diameter and up to 5 m high, although in the northwestern USA where spiracles are common they generally are 10 m in diameter and 12 m high or more; formed by a gaseous explosion in lava that is still fluid, probably due to steam generated from underlying wet material; smoother lava clots and drapes than a spatter cone.
Spit	(a) A small point or low tongue of narrow enbakment of land, commonly consisting of sand or gravel deposited by longshore transport and having one end attached to the mainland and the other terminating in open water, usually the sea; a fingerlike extension of the beach. (b) A relatively long, narrow shoal or reef extending from the shore into a body of water.
Spur	A subordinate ridge or lesser elevation that projects sharply from the crest or side of a hill, mountain, or other prominent range of hills or mountains.
Spur ridge	(not recommended) use spur.
Stack	(a) An isolated pillar-like rocky island or mass near a cliffy shore, detached from a headland by wave erosion assisted by weathering; especially one showing columnar structure with horizontal stratification. Examples occur along the Oregon coast and the Lake Superior shore. (b) A steep-sided mass of rock rising above its surroundings on all sides from a slope or hill.
Star dune	A large, isolated sand dune whose base, in plan view, resembles a star, with sharp-crested ridges converging from basal points to a central peak that may be as high as 100 m above the surrounding plain. It tends to remain fixed for centuries in an area where the wind blows from all directions.

Term	Definition
Stoss and lee	An arrangement of small hills or prominent rocks, in a strongly glaciated area, having gentle slopes on the stoss (“up-ice”) side and somewhat steeper, plucked slopes on the lee (“down-ice”) side. This arrangement is the opposite of crag and tail.
Strait	A relatively narrow waterway connecting two larger bodies of water, as the Straits of Mackinac linking Lake Michigan and Lake Huron; a large channel.
Strand plain	A prograded shore built seaward by waves and currents, and continuous for some distance along the coast. It is characterized by subparallel beach ridges and swales, in places with associated dunes.
Strandline	(a) The shoreline, especially a former (relict) shoreline now elevated above the present water level, that commonly appears as a bench or line wrapping around the landscape at a common elevation. (b) A beach, especially one raised above the present sea or lake level.
Strath terrace	A type of stream terrace, formed as an erosional surface cut on bedrock and thinly mantled (e.g. < 3 m) with stream deposits (alluvium), commonly with a gravel lag deposit immediately above the bedrock.
Stratovolcano	A volcano that is constructed of alternating layers of lava and pyroclastic deposits, along with abundant dikes and sills. Viscous, acidic lava may flow from fissures radiating from a central vent, from which pyroclastics are ejected.
Stream terrace	One, or a series of flat-topped landforms in a stream valley that flank and are parallel to the stream channel, originally formed by a previous stream level, and representing remnants of an abandoned flood plain, stream bed, or valley floor produced during a past state of fluvial erosion or deposition (i.e., currently very rarely or never flooded; inactive cut and fill and/or scour and fill processes). Erosional surfaces cut into bedrock and thinly mantled with stream deposits (alluvium) are called "strath terraces." Remnants of constructional valley floors thickly mantled with alluvium are called alluvial terraces.
Strike valley	A subsequent valley eroded in, and developed parallel to the strike of, underlying weak strata, such as a cuesta; a valley that commonly, but not necessarily contains a stream valley.
String bog	A peatland with roughly parallel, narrow ridges of peat dominated by peat vegetation interspersed with slight depressions, many of which contain shallow pools. The ridges are at right angles to low (< 2o) slopes. They are typically 1 to 3 m wide, up to 1 m high and may be over 1 km long. The ridges are slightly elevated and are better drained allowing shrubs and trees to grow. They are best developed in areas of discontinuous permafrost.
Stripe	A type of patterned ground; one of the alternating bands of fine and coarse surface material, or of rock or soil and vegetation-covered ground, commonly found on steeper slopes. It is usually straight, but may be sinuous or branching.
Structural bench	A platform-like, nearly level to gently inclined erosional surface developed on resistant strata in areas where valleys are cut in alternating strong and weak layers with an essentially horizontal attitude. Structural benches are bedrock controlled, and in contrast to stream terraces, have no geomorphic implication of former, partial erosion cycles and base-level controls, nor do they represent a stage of floodplain development following an episode of valley trenching.
Submerged back-barrier beach	A permanently submerged extension of the back-barrier beach that generally parallels the boundary between estuary and the barrier island.
Submerged mainland beach	A permanently submerged extension of the mainland beach that generally parallels the boundary between an estuary or lagoon and the mainland.
Submerged point bar	The submerged extension of an exposed (subaerial) point bar.
Submerged wave-built terrace	A subaqueous, relict depositional landform originally constructed by river or longshore sediment deposits along the outer edge of a wave-cut platform and later submerged by rising sea level or subsiding land surface.
Submerged wave-cut platform	A subaqueous, relict erosional landform that originally formed as a wavecut bench and abrasion platform from coastal wave erosion and later submerged by rising sea level or subsiding land surface
Submerged-upland tidal marsh	An extensive nearly level, intertidal landform composed of unconsolidated sediments (clays, silts, and/or sand and organic materials), a resistant root mat,

Term	Definition
	vegetated dominantly by hydrophytic (water loving) plants. The mineral sediments largely retain pedogenic horizonation and morphology (e.g. argillic horizons) developed under subaerial conditions prior to submergence due to sea level rise; a type of tidal marsh.
Subsidence area (natural)	An area subject to a process of subsidence due to natural causes
Summit	(a) The topographically highest position of a hillslope profile with a nearly level (planar or only slightly convex) surface. (b) A general term for the top, or highest area of a landform such as a hill, mountain, or tableland. It usually refers to a high interfluve area of relatively gentle slope that is flanked by steeper slopes, e.g., mountain fronts or tableland escarpments.
Swale	(a) A shallow, open depression in unconsolidated materials which lacks a defined channel but can funnel overland or subsurface flow into a drainageway. Soils in swales tend to be moister and thicker (cumulic) compared to surrounding soils. (b) A small, shallow, typically closed depression in an undulating ground moraine formed by uneven glacial deposition; Compare - swell-and-swale topography. (c) (not preferred; refer to interdune) A long, narrow, generally shallow, trough-like depression between two beach ridges, and aligned roughly parallel to the coastline.
Swallow hole	A closed depression or doline into which all or part of a stream disappears underground.
Swamp	An area of low, saturated ground, intermittently or permanently covered with water, and predominantly vegetated by shrubs and trees, with or without the accumulation of peat.
Swash zone	The sloping part of the beach that is alternately covered and uncovered by the uprush of waves, and where longshore movement of water occurs in a zigzag (upslope-downslope) manner.
Tableland	A general term for a broad upland mass with nearly level or undulating summit area of large extent and steep side slopes descending to surrounding lowlands (e.g. a large plateau).
Talus	Rock fragments of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep rock slope. The accumulated mass of such loose broken rock formed chiefly by falling, rolling, or sliding.
Talus cone	(a) A steep (e.g. 30 - 40º), cone-shaped landform at the base of a cliff or escarpment that heads in a relatively small declivity or ravine, and composed of poorly sorted rock and soil debris that has accumulated primarily by episodic rockfall or, to a lesser degree, by slope wash. Finest material tends to be concentrated at the apex of the cone. Not to be confused with an alluvial cone; a similar feature but of fluvial origin, composed of better stratified and more sorted material, and that tapers up into a more extensive drainageway. (b) A small cone-shapped or apron-like landform at the base of a cliff, consisting of poorly sorted debris that has accumulated episodically by rockfall or alluvial wash. (c) Also, a similar feature of fluvial origin, tapering into a gully.
Talus slope	A steep, concave slope formed by an accumulation of loose rock fragments; especially such a slope at the base of a cliff, formed by the coalescence of of several rockfall taluses or alluvial taluses; the surface profile of an accumulation of talus.
Tank	(colloquial: southwestern USA) A natural depression or cavity in impervious rocks in which water collects and remains for the greater part of the year.
Tarn	A relatively deep, steep-banked lake or pool occupying an ice-gouged rock basin amid glaciated mountains. A cirque lake.
Terminal fan	An alluvial fan that occurs in arid basins of inland drainage where the stream flow is ephemeral. Channels split into networks of distributries and subfans develop on a larger fan form.
Terminal moraine	Ridge of unconsolidated debris deposited or pushed up at the snout or end of the glacier.
Terrace	A step-like surface, bordering a valley floor or shoreline, that represents the former position of a flood plain, or lake or sea shore. The term is usually applied to both

Term	Definition
	the relatively flat summit surface (tread), cut or built by stream or wave action, and the steeper descending slope (scarp, riser), graded to a lower base level of erosion.
Terrace slope	The scarp or bluff below the outer edge of a terrace; the front or face of a terrace.
Terracettes	Small, irregular step-like forms on steep hillslopes, especially in pasture, formed by creep or erosion of surficial materials that may be induced or enhanced by trampling of livestock such as sheep or cattle. Synonyms (not preferred) - catstep, sheep or cattle track.
Thalweg	The line of continuous maximum descent from any point on land surface; e.g. the line of greatest slope along a valley floor, or the line crossing all contour lines at right angles, or the line connecting the lowest points along the bed of a stream.
Thermokarst	Karst-like topographic features produced in a permafrost region by local melting of ground ice and subsequent settling of the ground.
Thermokarst depression	A hollow in the ground resulting from subsidence following the local melting of ground ice in a permafrost region.
Thermokarst drainage pattern	Drainage patterns that form polygonal and hexagonal shapes with streams that may connect rounded depressions, exhibiting a beaded appearance; developed in poorly drained, finegrained sediments and in organic materials in regions of permafrost. Freezing causes many cracks to develop; thawing causes slumping, settlement, and depressions. This type of drainage pattern with its associated hexagons and beaded ponds indicates the existence or previous presence of permafrost conditions.
Thermokarst lake	Lake or pond produced in a permafrost region by melting of ground ice.
Tidal channel	(a) A major channel followed by tidal currents, extending from offshore into a tidal marsh or a tidal flat.
Tidal delta	A delta formed at the mouth of a tidal inlet on either the seaward or the lagoon side of a barrier island or baymouth bar by changing tidal currents that sweep sand in and out of the inlet.
Tidal flat	An extensive, nearly horizontal, barren or sparsely vegetated tract of land that is alternately covered and uncovered by the tide, and consists of unconsolidated sediment (mostly clays, silts and/or sands and organic materials).
Tidal inlet	Any inlet through which water alternately floods landward with the rising tide and ebbs seaward with the falling tide.
Tidal marsh	An extensive, nearly level marsh bordering a coast (as in a shallow lagoon, sheltered bay or estuary) and regularly inundated by high tides; formed mostly of unconsolidated sediments (e.g. clays, silts, and/or sands and organic materials), and the resistant root mat of salt tolerant plants; a marshy tidal flat
Till plain; Moraine landscape	An extensive, flat to gently undulating area underlain predominantly by till and bounded on thedistal end by subordinate recessional or end moraines.
Till-floored lake plain	[soil survey] The floor of an extinct glacial lake where a thin (e.g. < 2 m), often discontinuous veneer of lacustrine sediments overlies till. Commonly its topography reflects the underlying, irregular or undulating till surface rather than a distinctive, flat, lake plain surface. It may include subdued, till-capped topographic highs, ringed by shore deposits or strandlines, which were once emergent islands.
Toe	The lowest, usually curved margin of displaced material of a landslide, most distant from the main scarp. Commonly it has an irregular surface that has ripples and may be breached by radial cracks or gaps.
Toeslope	The hillslope position that forms the gently inclined surface at the base of a hillslope. Toeslopes in profile are commonly gentle and linear, and are constructional surfaces forming the lower part of a hill-slope continuum that grades to valley or closed-depression floors.
Tombolo	A sand or gravel bar or barrier that connects an island with the mainland or with another island
Tor	A high, isolated pinnacle, or rocky peak; or a pile of rocks, much-jointed and usually granitic, exposed to intense weathering, and often assuming peculiar or fantastic shapes .
Toreva block	A slump block consisting of a single large mass of unjostled material which, during descent, has undergone a backward rotation toward the parent cliff along a

Term	Definition
	horizontal axis that roughly parallels it; a type of rotational landslide. The unit forms a crude, elongated rectangular block rather than a bowl shape or chaotic mass; typically associated with horizontal to gently dipping, interbedded bedrock (e.g. Black Mesa area, NM).
Tower karst	(a) A type of tropical karst topography characterized by isolated, steep-sided, residual limestone hills or ridges with vertical or near-vertical walls, and may be relatively flat-topped; commonly surrounded by a flat alluvial plain or lagoons. (Also called fenglin). (b) A cluster of peaks or ridges with vertical or near-vertical walls, and convex upper side slopes where towers rise from a common base and are separated by deep, rugged ravines or large sinkholes. (Also called fengcong, turmkarst).
Translational debris slide	The process, associated sediments (translational debris slide deposit) or resultant landform characterized by an extremely slow to moderately rapid type of slide, composed of comparatively dry and largely unconsolidated earthy material, portions or blocks of which remain largely intact and in which movement occurs along a well-defined, planar slip face roughly parallel to the ground surface and resulting in lateral displacement but no rotation of the displaced mass; sediments have substantial proportions of both fine earth and coarse fragments. The landform may be single, successive (repeated up anddown slope), or multiple (as the number of slide components increase).
Translational earth slide	The process, associated sediments (translational earth slide deposit) or resultant landform characterized by an extremely slow to moderately rapid type of slide, composed of comparatively dry and largely unconsolidated earthy material, portions or blocks of which remain largely intact and in which movement occurs along a well-defined, planar slip face roughly parallel to the ground surface and resulting in lateral displacement but no rotation of the displaced mass; sediments predominantly fine earth (< 2 mm). The landform may be single, successive (repeated up and down slope), or multiple (as the number of slide components increase).
Translational rock slide	The process, associated sediments (translational rock slide deposit) or resultant landform characterized by an extremely slow to moderately rapid type of slide, composed of comparatively dry and largely consolidated rock bodies, portions or blocks of which remain largely intact and in which movement occurs along a well-defined, planar slip face roughly parallel to the ground surface and resulting in lateral displacement but no rotation of the displaced mass; sediments predominantly fine earth (< 2 mm). The landform may be single, successive (repeated up and down slope), or multiple (as the number of slide components increase).
Translational slide	A category of mass movement processes, associated sediments (translational slide deposit) or resultant landforms characterized by the extremely slow to moderately rapid downslope displacement of comparatively dry soil-rock material on a surface (slip face) that is roughly parallel to the general ground surface, in contrast to falls, topples, and rotational slides. The term includes such diverse slide types as translational debris slides, translational earth slide, translational rock slide, block glides, and slab or flake slides.
Transverse bar	Common features of sandy, low sinuosity streams, but they also occur in gravel-bed streams.
Transverse dune	A very asymmetric sand dune elongated perpendicular to the prevailing wind direction, having a gentle windward slope and a steep leeward slope standing at or near the angle of repose of sand; it generally forms in areas of sparse vegetation.
Tree-tip pit and mound topography	A local-scale topography composed of irregularly spaced, small, closed depressions and adjacent mounds caused by the displacement of root balls from trees knocked down by wind (i.e., tree-tip; also called tree-throw). The result is a subdued, irregularly pock-marked or undulating surface; most common in forested areas overlying shallow rooting conditions (e.g., lithic contact, water table, etc). Micro-elevational differences generally range from 0.5 to < 2 m. Sometimes also

Term	Definition
	referred to as (not preferred:) cradle and knoll, or pit and mound topography.
Tree-tip-mound	The small mound of debris sloughed from the root plate (root ball) of a tipped-over tree. Sometimes called a cradle knoll (not recommended). Local soil horizons are commonly obliterated and result in heterogeneous strata.
Tree-tip-pit	The small pit or depression resulting from an area vacated by the root plate (ball) resulting from tree-tip ("tree-throw"). Such pits are commonly adjacent to small mounds composed of the displaced material. Subsequent infilling commonly results in a heterogeneous soil matrix that may or may not include a stone line that lines the depression.
Trellis drainage pattern	A drainage pattern characterized by parallel main streams intersected at, or nearly at, right angles by their tributaries, which in turn are fed by elongated secondary tributaries and short gullies parallel to the main streams, resembling, in plan view, the stems of a vine on a trellis. This pattern indicates marked bedrock structural control rather than a type of bedrock and usually indicates in which the main parallel channels follow the strike of the beds. It is commonly developed where the beveled edges of alternating hard and soft rocks outcrop in parallel belts, as in titled, interbedded sedimentary rocks in a rejuvenated folded-mountain region or in a maturely dissected belted coastal plain of tilted strata.
Trough	(a) Any long, narrow depression in the earth's surface, such as one between hills or with no surface outlet for drainage. (b) (not preferred – see U-shaped valley, mountain valley) A broad, elongate U-shaped valley, such as a glacial trough
Tumulus	A small dome or mound on the surface of a lava flow formed by the buckling of the congealing crust near the edge of a flow caused by differences in flow rates of the cooler crust above and the hotter, more fluid lava below. Dimensions commonly range from < 1 m to 5 m in height, 3 to 10 m in width and 30 to 40 m in length. Some tumuli are hollow.
Tunnel valley	A relatively shallow trench or depression cut into drift and other loose material, or in bedrock, by a subglacial stream not loaded with coarse sediment that may or may not be part of the present day drainage pattern.
Tunnel-valley lake	A glacial lake occupying a portion of a tunnel valley.
Turf hummock	A hummock consisting of vegetation and organic matter with or without a core of mineral soil or stones.
Underfit stream	A stream that appears to be too small to have eroded the valley in which it flows; a stream whose volume is greatly reduced or whose meanders show a pronounced shrinkage in radius. It is a common result of drainage changes effected by capture, glaciers, or climatic variations.
Upland	An informal, general term for (a) the higher ground of a region, in contrast with a low-lying, adjacent land such as a valley or plain. (b) Land at a higher elevation than the flood plain or low stream terrace; land above the footslope zone of the hillslope continuum.
U-shaped valley	A valley having a pronounced parabolic cross profile suggesting the form of a broad letter "U", with steep walls and a broad, nearly flat floor; specifically a valley carved by glacial erosion.
Valley	An elongate, relatively large, externally drained depression of the Earth's surface that is primarily developed by stream erosion or glacial activity.
Valley border surfaces	A general grouping of valley-side geomorphic surfaces of relatively large extent that occur in a stepped sequence graded to successively lower stream base levels, produced by episodic valley entrenchment; for example, multiple stream terrace levels, each with assemblages of constituent landforms (e.g. interfluves, hillslopes, fans, etc.) that dominate the margins of large river valleys.
Valley flat	A generic term for the low or relatively level ground lying between valley walls and bordering a stream channel; especially the small plain at the bottom of a narrow, steep-sided valley. The term can be generally applied noncommittally to a flat surface that cannot be identified with certainty as a floodplain or terrace.
Valley floor	A general term for the nearly level to gently sloping, lowest surface of a valley. Landforms include axial stream channels, the flood plain, flood-plain steps, and, in some areas, low terrace surfaces.
Valley floor remnant	Hills that are now erosion remnants of a former valley or basin floor, composed

Term	Definition
	mostly of unconsolidated valley / basin fill sediments (e.g. alluvium) and typically lie well above the modern valley floor and flood plain. Former basin floor surfaces have become dissected and irregular and consist of hillslope positions (shoulder, backslope, etc.) and hill components (interfluve, headslope, etc.); common in large valleys of the western US.
Valley train	A long narrow body of outwash confined within a valley beyond a glacier; it may, or may not, emerge from the valley and join an outwash plain.
Vernal pool	A natural, seasonal pond in a small closed depression (micro-low) which supports a semiaquatic or aquatic ecosystem adapted to annual cycles of standing water in the springtime followed by drying in the summer / autumn; commonly recognized in CA.
Volcanic center	A site at which volcanic activity localized at one or several vents is occuring or has occured in the past
Volcanic cone	A conical hill of lava and/or pyroclastics that is built up around a volcanic vent.
Volcanic dome	A steep-sided, rounded extrusion of highly viscous lava squeezed out from a volcano, and forming a dome-shaped or bulbous mass of congealed lava above and around the volcanic vent
Volcano	A vent in the surface of the Earth through which magma and associated gases and ash erupt; also, the form or structure, usually conical, that is produced by the ejected material.
V-shaped valley	A valley having a pronounced cross profile suggesting the form of the letter "V", characterized by steep sides and short tributaries; specifically a narrow valley resulting from downcutting by a stream. The "V" becomes broader as the downcutting progresses.
Wash (dry wash)	(colloquial: western U.S.A.) The broad, flat-floored channel of an ephemeral stream, commonly with very steep to vertical banks cut in alluvium. Note: When channels reach intersect zones of ground-water discharge they are more properly classed as "intermittent stream" channels. Synonym - arroyo.
Washover fan	A fan-like deposit of sand washed over a barrier island or spit during a storm and deposited on the landward side. Washover fans can be small to medium sized and completely subaerial, or they can be quite large and include subaqueous margins extending into adjacent lagoons or estuaries. Large fans can be subdivided into sequential parts: ephemeral washover channel (microfeature) cut through dunes or beach ridges, back-barrier flats, (subaqueous) washover-fan flat, (subaqueous) washover-fan slope. Subaerial portions can range from barren to completely vegetated.
Wave-built terrace	A gently sloping coastal feature at the seaward or lakeward edge of a wave-cut platform, constructed by sediment brought by rivers or drifted along the shore or across the platform and deposited in the deeper water beyond.
Wave-cut platform	A gently sloping surface produced by wave erosion, extending into the sea or lake from the base of the wave-cut cliff. This feature represents both the wave-cut bench and the abrasion platform
Wind gap	A former water gap now abandoned by the stream that formed it, suggesting stream piracy or stream diversion.
Wind-tidal flat	A broad, low-lying, nearly-level sand flat that is alternately inundated by ponded rainwater or by wind-driven bay or estuarine water from storm surges or seiche. Frequent salinity fluctuations and prolonged periods of subaerial exposure preclude establishment of most types of vegetation except for mats of filamentous blue-green algae.
Yardang	(a) A microfeature in the form of a long, irregular, sharp-crested, undercut ridge between two round-bottomed troughs, carved on a plateau or unsheltered plain in a desert region by wind erosion, and cut into soft but coherent deposits (such as clayey sand); it lies in the direction of the dominant wind, and may be up to 6 m high and 40 m wide. (b) A landform produced in a region of limestone or sandstone by infrequent rains combined with wind action, and characterized by “a surface bristling with a fine lacework of sharp ridges pitted by corrosion”.
Yardang through	A long, shallow, round-bottomed groove, furrow, trough, or corridor excavated in the desert floor by wind abrasion, and separating two yardangs.

Term	Definition
Zibar	A small, low-relief sand dune that lacks discernible slip faces and commonly occurs on sand sheets, in interdune areas, or in corridors between larger dunes. Zibar spacing can range from 50 – 400 m with local relief < 10 m. Unlike coppice dunes, zibars are not related to deposition around vegetation. Generally dominated by coarser sands.

NetworkNameValue

Code list

Term	Definition
IMS	IMS Seismological network
UEGN	Station is part of the Unified European Gravity Network
WDC	Station data is reported to World Data Center

PhysicalPropertyTerm

Code list

Term	Definition
bulk modulus/incompessibility	K, bulk modulus/incompessibility
compressional wave velocity	
compressive strength	
density	Material mass per unit volume
fault strength	
Fracture toughness	
magnetic dipole moment/unit volume	SI unit A/m
magnetic susceptibility	Material magnetic susceptibility, customarily measured in SI units. The ratio of induced magnetization to the strength of the magnetic field causing the magnetization.Note that volume magnetic susceptibility is dimensionless, being magnetization (magnetic dipole moment) in amperes per metre (SI) divided by the applied field, also in amperes per metre. However, many tables of magnetic susceptibility and some instruments give cgs values that rely on different definitions of the permeability of free space than SI values. The cgs value of susceptibility is multiplied by 4pi to give the SI susceptibility value. For example, the cgs volume magnetic susceptibility of water at 20&#65533;C is -7.19x10-7 which is -9.04x10-6 in SI. The xml encoding should specify whether the uom is SI or cgs, and if in cgs provide a <gml:conversionToPreferredUnit>.
permeability	The measure of the capacity of a porous material to transmit a fluid under unequal pressure. Customary unit of measure: millidarcy
poisson's ration	
porosity	The percentage of the bulk volume of a material that is occupied by interstices, whether isolated or connected.
radioactive activiy	SI unit is the becquerel, Bq, transformations per second
resistivity	
Seismic attenuation	Q, Seismic attenuation
shear modulus/rigidity	
shear velocity in the horizontal plane	vSH, shear velocity in the horizontal plane
shear velocity in the vertical plane	vSV, shear velocity in the vertical plane
shear wave velocity	

Term	Definition
sliding stability	
specific heat	
thermal conductivity	

PlanarPolarityCode

Code list

Term	Definition
not applicable	A planar orientation is not applicable (eg foliations)
overturned	The plane is overturned (eg the bedding is overturned)
unknown	A planar orientation is applicable but it is unknown.
upright	The plane is upright (eg bedding is upright facing)
vertical	The plane is vertical (neither upright nor overturned)

PlatformTypeValue

Code list

Term	Definition
fixWingedAirplane	Measurement carried out from fix winged airplane
ground	Ground based measurement
helycopter	Measurement carried out from helycopter
researchVessel	Measurement carried out from a ship
satellite	Measurement carried out from a satellite

ProfileTypeValue

Code list

Term	Definition
boreholeLogging	Geophysical measurement in a borehole
seismicLine	Seismic measurement alon a line

ProjectedGeometryTypeValue

Code list

Term	Definition
footPrint	object is represented by it's 2D bounding polygon
point	object is represented by a reference point
trace	object is represented as a curve on the surface

RankTerm

Code list
(CGI_Term, Class: GeologicUnit, Attribute: rank)

Term	Definition
Bed	The smallest formal lithostratigraphic unit, usually a distinctive lithic entity which can be distinguished from adjacent rocks by one or more physical characteristics.
Formation	A body of rock identified by lithic characteristics and stratigraphic position; it is

Term	Definition
	usually but not necessarily tabular and is mappable at the Earth's surface or traceable in the subsurface.
Group	A group is the lithostratigraphic unit next higher in rank to either subgroup or formation. A groups may consist of two or more subgroups or two or more formations or a combination of both.
Lithodeme	A body of predominantly intrusive, highly deformed and/or highly metamorphosed rock, distinguished and delimited on the basis of rock characteristics.
Megasequence	A succession of strata comprising two or more supersequences. A large-scale sequence-stratigraphic unit deposited during one distinct phase of basin evolution, separated by major unconformities that mark a change in fundamental basin-controlling processes.
Member	A formal lithostratigraphic unit next in rank below a formation, and always part of a formation. It is a named entity within a formation because it possesses characteristics distinguishing it from adjacent parts of the formation.
Not specified	unit is not part of a defined stratigraphic hierarchy.
Sequence	A genetically related succession of strata bounded by unconformites or their correlative conformable contacts, and typically having a thickness of 10-100 metres.
Subgroup	A subgroup is the lithostratigraphic unit next higher in rank to formation. A subgroup usually consists of several formations.
Suite	A formal lithodemic unit next higher in rank to lithodeme. It comprises two or more associated lithodemes of the same class (e.g., plutonic, metamorphic).
Supergroup	A supergroup is a formal assemblage of related or superposed groups or of groups and formations
Supersequence	A succession of strata comprising two or more sequences
Supersuite	A formal lithodemic unit next higher in rank to suite. It comprises two or more suites having a degree of natural relationship to one another

SeismicLineTypeValue

Enumeration

Term	Definition
2D	
3D	

SolidGridModelTypeValue

Code list

Term	Definition
parameterBlock	Model describing geophysical property distribution represented as a 3 dimensional grid.
seismicVolume	Model describing seismic reflectivity distribution represented as a 3 dimensional grid.

SolidModelTypeValue

Code list

Term	Definition

StateOfGWB

Enumeration

Term	Definition
lightlyModified	
modified	
natural	
stronglyModified	

StationLevel

Enumeration

Term	Definition
baseLine	
basicNetwork	
hydrologicalBenchmark	
specificNetwork	
temporalNetwork	

StationRankValue

Code list

Term	Definition
1stOrderBase	Base station of higher importance
2ndOrderBase	Base station of lower importance
normal	Ordinary survey station
observatory	Permanent monitoring facility with continuous observation scedule.
secularStation	Base station to observ long term time variations. Applied to magnetic stations.

StationType

Enumeration

Term	Definition
quality	
quantity	

StationTypeValue

Code list

Term	Definition
gravityStation	Gravity measurement station
magneticStation	Magnetic measurement station
seismologicalStation	Seismologic measurement station

SurfaceGridModelTypeValue

Code list

Term	Definition
horizontalParameterGrid	Model describing geophysical property distribution represented as a grid in a

Term	Definition
	horizontal plain.
seismicDepthSection	Model describing seismic reflectivity distribution represented as a grid in a vertical plain.
verticalParameterGrid	Model describing geophysical property distribution represented as a grid in a vertical plain.

SurfaceModelTypeValue

Code list

Term	Definition
horizontalCrossSection	Model describing geophysical property distribution represented as polygon patches in a horizontal plain.
verticallCrossSection	Model describing geophysical property distribution represented as polygon patches in a vertical plain.

SurfaceScanningTypeValue

Code list

Term	Definition
radarBathimetry	Radar bathimetry measurement
radarInterferometry	Radar interferometry measurement

ValueQualifierCode

Code list
(CGI_Term, Class: CGI_Term, Attribute: qualifier)

Term	Definition
always	all instances of the observed entity have this property value
approximate	specified value is approximate
common	reported property value is commonly observered
equalTo	reported property value is the observered value
greaterThan	reported property value is lower bound
lessThan	reported property value is upper bound
never	reported property value is never observed
rare	reported property value is rarely observed.
sometimes	reported property value is observed occasionally

WaterPersistenceValue

Code list

Term	Definition
ephemeral	Filled and/or flowing during and immediately after precipitation. SOURCE [DFDD].
intermittent	Filled and/or flowing for part of the year. SOURCE [DFDD].
perennial	Filled and/or flowing continuously throughout the year as its bed lies below the water table. SOURCE [DFDD].
seasonal	

WaterType

Enumeration

Term	Definition
acratopegae	From Ancient Greek akratos ("pure, unmixed") and PEGE ("source, fountain). Water with low mineral content or less than mineral water. Translated from : Du grec ancien akratos (" pur, sans melange ") et pege (" source, fontaine "). Qui a, en parlant d'une eau, une faible teneur en sels mineraux ou une teneur moindre que celle d'une eau minerale. http://fr.wiktionary.org/wiki/acratop%C3%A8ge
brackishWater	Brackish water (less commonly brack water) is water that has more salinity than fresh water, but not as much as seawater. It may result from mixing of seawater with fresh water, as in estuaries, or it may occur in brackish fossil aquifers. The word comes from the Middle Dutch root "brak," meaning "salten" or "salty" http://en.wikipedia.org/wiki/Brackish
brineWater	Brine (lat. saltus) is water saturated or nearly saturated with salt (NaCl). http://en.wikipedia.org/wiki/Brine
freshWater	A- Freshwater is a word that refers to bodies of water such as ponds, lakes, rivers and streams containing low concentrations of dissolved salts and other total dissolved solids. In other words, the term excludes seawater and brackish water. Freshwater can also be the output of desalinated seawater. http://en.wikipedia.org/wiki/Freshwater Fresh water: Water with less than 0.5 parts per thousand dissolved salts.
saltWater	Saline water is a general term for water that contains a significant concentration of dissolved salts (NaCl). The concentration is usually expressed in parts per million (ppm) of salt. The salinity concentration level used by United States Geological Survey classifies saline water in three categories. Slightly saline water contains around 1,000 to 3,000 ppm. Moderately saline water contains roughly 3,000 to 10,000 ppm. Highly saline water has around 10,000 to 35,000 ppm of salt. Seawater has a salinity of roughly 35,000 ppm, equivalent to 35 g/L. Technically, brackish water contains between 0.5 to 30 grams of salt per litre?more often expressed as 0.5 to 30 parts per thousand (ppt). Thus, brackish covers a range of salinity regimes and is not considered a precisely defined condition. http://en.wikipedia.org/wiki/Saline_water
ultraFreshWater	TBD

WaterUseCode

Code list

Term	Definition
Agriculture	Agricultural Use. The use of any tract of land for the production of animal or vegetable life; uses include, but are not limited to, the pasturing, grazing, and watering of livestock and the cropping, cultivation, and harvesting of plants. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-a.pdf
Commercial	Commercial Water Use (Withdrawals). Water for motels, hotels, restaurants, office buildings, and other commercial facilities and institutions, both civilian and military. The water may be obtained from a public supply or may be self supplied. The terms "water use" and "water withdrawals" are equivalent, but not the same as "Consumptive Use" as they do not account for return flows. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-c.pdf
Domestic	Domestic Water Use (Withdrawals). Water used normally for residential purposes, including household use, personal hygiene, drinking, washing clothes and dishes, flushing toilets, watering of domestic animals, and outside uses such as car washing, swimming pools, and for lawns, gardens, trees and shrubs. The water may be obtained from a public supply or may be self supplied. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-d.pdf
HeatTransfert	Water used as an agent to facilitate heat trasfer. Heat Transfer Agent. A liquid or gas that functions in a Heat Exchanger to facilitate the movement of heat from one location to another. For example, the engine coolant in an automobile serves to

Term	Definition
	transfer heat from the engine block to the atmosphere. likewise, water facilitates the movement of heat from the reactor core to the outside of a nuclear reactor. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-h.pdf
Industrial	Industrial Water Use (Withdrawals) ? Industrial water use includes water used for processing activities, washing, and cooling. Major water-using manufacturing industries include food processing, textile and apparel products, lumber, furniture and wood products, paper production, printing and publishing, chemicals, petroleum, rubber products, stone, clay, glass and concrete products, primary and fabricated metal industries, industrial and commercial equipment and electrical, electronic and measuring equipment and transportation equipment. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-i.pdf
Irrigation	Irrigation Water Use (Withdrawals). Artificial application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth on recreational lands, such as parks and golf courses. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-i.pdf
Municipal	M&I (Municipal and Industrial) Water Withdrawals (Use). Water supplied for municipal and industrial uses provided through a municipal distribution system. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-m.pdf Public Water Use. Water supplied from a Public Water Supply System (PWSS) and used for such purposes as fire fighting, street washing, and municipal parks, golf courses, and swimming pools. Public water use also includes system water losses (water lost to leakage) and brine water discharged from desalination facilities. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-p.pdf
OtherUnknow	Other Water Use. Water used for such purposes as heating, cooling, irrigation (public-supplied only), lake augmentation, and other nonspecific uses. http://water.nv.gov/WaterPlanning/dict-1/PDFs/wwords-o.pdf
PublicRecreation	TBD
Research	TBD

WellPurposeCode

Code list

Term	Definition
cathodicProtection	Other, less common types of wells include cathodic protection wells. Cathodic protection wells, sometimes called 'deep groundbeds,' house devices to minimize electrolytic corrosion of metallic pipelines, tanks, and other facilities in contact with the ground. http://www.dpla.water.ca.gov/sd/groundwater/california_well_standards/cpws/cpws_introduction.html
coalELog	TBD
core	TBD
decontamination	TBD
dewatering	ewatering is the removal of water from solid material or soil by wet classification, centrifugation, filtration, or similar solid-liquid separation processes. Removing or draining water from a riverbed, construction site, caisson, or mine shaft, by pumping or evaporation. This is often done during the site development phase of a major construction project due to a high water table. Usually involves the use of "dewatering" pumps. Methods of dewatering include; Wellpoint, Deep Well and Eductor systems. http://en.wikipedia.org/wiki/Dewatering
disposal	A well, often a depleted oil or gas well, into which waste fluids can be injected for safe disposal. Disposal wells typically are subject to regulatory requirements to avoid the contamination of freshwater aquifers. http://www.glossary.oilfield.slb.com/Display.cfm?Term=disposal%20well
flowingShot	A flowing shot hole is a drilled (seismic) hole that has entered an underground water source that has sufficient pressure to cause the hole to "overflow". http://www.etsurvey.com/water/h20main.htm

Term	Definition
geotechnical	A geotechnical well is defined as a hole drilled for the exclusive purpose of collecting geotechnical data, including soil samples, vapour samples, and water samples obtained through bailing, driven sampler or other similar methods. http://www.adwr.state.az.us/dwr/Content/Find_by_Category/Laws_and_Rules/files/SPS/Well%20Construction/Well%20Construction%20and%20LIcensing%20-%20WL7.pdf
mineral	A non-E&P well drilled for the purpose of locating and/or extracting a mineral from the subsurface, usually through the injection and/or extraction of mineral-bearing fluids. http://posc.org/technical/reference/POSC_well_purpose.html Mineral test hole- any hole in excess of one hundred (100) feet drilled during the exploration for minerals but shall exclude auger drilling in surficial or otherwise unconsolidated material, drilling in conjunction with mining or quarrying operations, and drill holes for the exploration of oil and/or gas, water, structural foundations, and seismic surveys. http://www.tennessee.gov/sos/rules/0950/0950-01-01.pdf
monitoringLevelHead	Monitoring well: A non-pumping well, generally of small diameter, that is used to measure the elevation of a water table or water quality. A piezometer, which is open only at the top and bottom of its casing, is one type of monitoring well. http://www.groundwater.org/gi/gwglossary.html#M monitoring wells or piezometers, are often smaller diameter wells used to Monitor the hydraulic head or sample the groundwater for chemical constituents. Piezometers are monitoring wells completed over a very short section of aquifer. Monitoring wells can also be completed at multiple levels, allowing discrete samples or measurements to be made at different vertical elevations at the same map location. http://en.wikipedia.org/wiki/Monitoring_well
monitoringQuality	Most monitoring wells constructed today are used to assess the nature and distribution of pollutants and contaminants in groundwater; The nature and distribution of naturally occurring chemical constituents; Subsurface hydrologic conditions; and, hydraulic properties of strata as they relate to pollutant and contaminant movement. http://www.dpla.water.ca.gov/sd/groundwater/california_well_standards/mws/mws_history.html
oil	An oil well is a term for any perforation through the Earth's surface designed to find and release both petroleum oil and gas hydrocarbons. http://en.wikipedia.org/wiki/Oil_well
oilExploratory	A exploratory well drilled in an unproved area to test for a new field, a new pay, a deeper reservoir, or a shallower reservoir. Also known as an exploration well. http://posc.org/technical/reference/POSC_well_purpose.html Exploratory Well: A well drilled with a high degree of risk to: A) search for a new reservoir of oil or gas, also known as a Wildcat, B) extend the parameters of an existing field known as a Step Out, C) to prove another zone within an already producing field. http://www.vastenergy.com/definitions.htm
other	Any other usage of a well.
recharge	a- Aquifer Recharge Wells (5R21) Used to recharge depleted aquifers and may inject fluids from a variety of sources such as lakes, streams, domestic wastewater treatment plants, other aquifers, etc. b- Saline Water Intrusion Barrier Wells (5B22) Used to inject water into fresh water aquifers to prevent intrusion of salt water into fresh water aquifers. Used in highly populated areas. c- Subsidence Control Wells (5S23) Used to inject fluids into a non-oil or gas-producing zone to reduce or eliminate subsidence associated with overdraft of fresh water and not used for the purpose of oil or natural gas production. a, b, c - http://www.epa.gov/Region2/water/compliance/wellclasstypetable_inventoryc_form.pdf
seismic	A well used to conduct seismic surveys.
termal	
waterExploratory	A well drilled to seach for new groundwater
waterSupply	Well used to supply water for various usage.
withdrawal	TBD

WellStatusCode

Code list

Term	Definition
abandoned	
abandonedDry	
abandonedInsufficient	
abandonedQuality	
deepened	
new	
notInUse	
reconditionned	
standby	
unfinished	
unknown	

WellUse

Code list

Term	Definition
domestic	
exploitation	
monitoring	
observation	
piezometry	
production	

X3DMeasurementTypeValue

Code list

Term	Definition
3DMultielectrodeDC	Complex electrode array to measure 3D electric reistivity data
3DSeismics	

XDataSetTypeValue

Code list

Term	Definition
1DResistivitySurvey	1D resistivity survey. Vertical Electric Soundings
2DResistivitySurvey	2D resistivity survey. Multielectrode DC profiles
2DSeismicSurvey	2D seismic survey
3DResistivitySurvey	3D resistivity survey. Multielectrode DC measurements
3DSeismicSurvey	3D seismic survey
airborneGeophysicalSurvey	Airborne geophysical survey
boreholeLoggingSurvey	Borehole logging survey
frequencyDomainEMSurvey	Frequency domain EM survey
gravityObservatoryData	Data set from gravity field observatory

Term	Definition
Set	
gravitySurvey	Gravity survey
magneticObservatoryDataSet	Data set from magnetic field observatory
magneticSurvey	Magnetic measurement survey
magnetotelluricSurvey	Magnetotelluric survey
seismologicObservatoryDataSet	Data set from seismologic observatory
seismologicSurvey	Data set from seismologic observatory
timeDomainEMSurvey	Time domain EM survey

XProfileTypeValue

Code list

Term	Definition
boreholeLogging	Geophysical measurement in a borehole
conePenetrationTest	Cone penetration test
flightLine	Geophysical measurements along a line carried out from an airplane or helicopter
multielectrodeDCProfile	Multielectrode DC profile
seismicLine	Seismic measurement alon a line
verticalSeismicProfiling	Vertical seismic profile (VSP)

XStationTypeValue

Code list

Term	Definition
frequencyDomainEMSounding	Frequency domain electromagnetic sounding
gravityStation	Gravity measurement station
magneticStation	Magnetic measurement station
magnetotelluricSounding	Magnetotelluric sounding
seismologicalStation	Seismologic measurement station
timeDomainEMSounding	Time domain electromagnetic sounding
verticalElectricSounding	Vertical Electric Sounding