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OGC Geoscience Markup Language 4.1 (GeoSciML)

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i. Abstract

GeoSciML is a model of geological features commonly described and portrayed in geological maps, cross sections, geological reports and databases. The model was developed by the IUGS CGI (Commission for the Management and Application of Geoscience Information) and version 4.1 is the first version officially submitted as an OGC standard. This specification describes a logical model and GML/XML encoding rules for the exchange of geological map data, geological time scales, boreholes, and metadata for laboratory analyses. It includes a *Lite* model, used for simple map-based applications; a *basic* model, aligned on INSPIRE, for basic data exchange; and an *extended* model to address more complex scenarios.

The specification also provides patterns, profiles (most notably of Observations and Measurements - ISO19156), and best practices to deal with common geoscience use cases.

ii. Keywords

The following are keywords to be used by search engines and document catalogues.

Ogc doc, OGC document, geology, geoscience, stratigraphy, borehole, geochemistry, geophysics, rock, fault, contact, fold, fossil, UML, GML, XML.

iii. Preface

The primary goal of this specification is to capture the semantics, schema, and encoding syntax of key elements described and portrayed in geological maps and databases, in order to enable information systems to interoperate with such data.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights.

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

iv. Submitting organizations

The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

a) Arizona Geological Survey (AzGS), Arizona, USA
b) British Geological Survey (NERC-BGS), UK
c) Bureau de Recherches Géologiques et Minières (BRGM), France
d) Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
e) Geological Survey of Victoria (GSV), Australia

f) Geological Survey of Finland (GTK), Finland
g) Geological Survey of Italy (ISPRA), Italy
h) Geological Survey of Sweden (SGU), Sweden
i) Geoscience Australia (GA), Australia
j) Institute of Geological and Nuclear Sciences (GNS), New Zealand
k) Landcare Research, New Zealand
l) Natural Resources Canada (NRCan), Canada
m) U.S. Geological Survey (USGS), United States of America

v. Submitters

All questions regarding this submission should be directed to the editors or submitters:

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Marcus Sen	British Geological Survey	Y

1. Scope

GeoSciML (Geoscience Markup Language) covers the domain of geology (earth materials, geological units and stratigraphy, geological time, geological structures, geomorphology, geochemistry) and sampling features common to the practice of geoscience, such as boreholes and geological specimens. The specification also proposes a simplified version of GeoSciML suitable for portrayal of geological features on digital maps. This specification does not address (or very partially addresses) more specialised geoscience domains such as hydrogeology, seismology, geophysics or economic geology. Some of these domains are covered by other specifications (e.g. GroundwaterML for hydrogeology; OGC 16-032, and EarthResourceML for economic geology – both developed in concert with GeoSciML).

2. Conformance

This standard defines a logical model and an XML encoding which conform to OGC GML 3.3 encoding rules, itself, an iteration over ISO 19136 (2007).

Requirements for three standardization target types are considered:

- Logical Model
- Encoding
- Data instance.

Conformance with this standard shall be checked using all the relevant tests specified in Annex A (normative) of this document. The framework, concepts, and methodology for testing, and the criteria to be achieved to claim conformance are specified in the OGC Compliance Testing Policies and Procedures and the OGC Compliance Testing web site[1].

All requirements-classes and conformance-classes described in this document are owned by the standard(s) identified.

3. References

The following normative documents are referenced in the text or provide significant context for the development of GeoSciML 4.1. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this document are encouraged to investigate the

1 www.opengeospatial.org/cite

possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document applies.

- OGC 06-121r9, OGC® Web Services Common Standard
- ISO 19103:2005 - Conceptual Schema Language
- ISO 19107:2003 - Spatial Schema
- ISO 19108:2006 - Temporal Schema
- ISO 8601- Data elements and interchange formats – Information interchange – Representation of dates and times
- OGC Abstract Specification Topic 20 – Observations and Measurements (also ISO 19156:2011)
- OGC Abstract Specification Topic 2 – Spatial Referencing by Coordinates (also ISO 19111:2007)
- OGC Abstract Specification Topic 11 – Geographic information - Metadata (also ISO 19115:2003)
- OGC 07-036 Geography Markup Language (also ISO 19136:2007)
- OGC Observations and Measurements v2.0 OGC Document 10-004r1 http://www.opengis.net/doc/AS/Topic20 (also published as ISO/DIS 19156:2010, Geographic information - Observations and Measurements)
- OGC Observations and Measurements - XML Implementation v2.0 OGC Document 10-025r1 (http://www.opengis.net/doc/IS/OMXML/2.0)
- OGC SWE Common Data Model Encoding Standard v2.0 OGC Document 08-094r1 (http://www.opengis.net/doc/IS/SWECommon/2.0)
- RFC 3986 - Uniform Resource Identifier (URI): Generic Syntax, 2005. (http://www.rfc-base.org/rfc-3986.html)
- Schematron: ISO/IEC 19757-3, Information technology - Document Schema Definition Languages (DSDL) - Part 3: Rule-based validation - Schematron (http://standards.iso.org/ittf/PubliclyAvailableStandards/c040833_ISO_IEC_19757-3_2006(E).zip)
- The Specification Model - A Standard for Modular specifications OGC Document 08-131r3.
- Unified Code for Units of Measure (UCUM) - Version 2.0.1, 2014. (http://unitsofmeasure.org/ucum.html)
- Unified Modeling Language (UML). Version 2.3. May 2010.
- Extensible Markup Language (XML) - Version 1.0 (Fourth Edition), August 2006
- XML Schema - Version 1.0 (Second Edition), October 2004

- INSPIRE Data Specification for the spatial data theme Geology Version 3.0
- North American Data Model , especially the conceptual model (http://pubs.usgs.gov/of/2004/1334) and the science language products (http://ngmdb.usgs.gov/www-nadm/sltt/products.html)
- International Stratigraphic Guide, 1994. (http://www.stratigraphy.org/index.php/ics-stratigraphicguide)

4. Terms and Definitions

This document uses the terms defined in Sub-clause 5.3 of [OGC 06-121r8], which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word "shall" (not "must") is the verb form used to indicate a requirement to be strictly followed to conform to this standard.

For the purposes of this document, the following additional terms and definitions apply.

4.1
classifier
A classifier is an abstract UML metaclass which describes (classifies) a set of instances having common features (not to be confused with the "Feature" stereotype from the OGC Feature Model). A feature declares a structural or behavioral characteristic of instances of classifiers. (http://www.uml-diagrams.org/classifier.html). Classes, Interfaces, Association, and Types are kinds of classifiers.

4.2
domain feature
Feature of a type defined within a particular application domain.

NOTE: This may be contrasted with observations and sampling features, which are features of types defined for cross-domain purposes.

[ISO 19156, definition 4.4]

4.3
element <XML>
Basic information item of an XML document containing child elements, attributes and character data.

NOTE: From the XML Information Set — each XML document contains one or more elements, the boundaries of which are either delimited by start-tags and end-tags, or, for empty elements, by an empty-element tag. Each element has a type, identified by name, sometimes called its ‘generic identifier’ (GI), and may have a set of attribute specifications. Each attribute specification has a name and a value.

[ISO 19136:2007]

4.4
feature
Abstraction of a real-world phenomenon.

[ISO 19101:2002, definition 4.11]

4.5
GML application schema
Application schema written in XML Schema in accordance with the rules specified in OGC GML 3.3

[ISO 19136:2007]

4.6
GML document
XML document with a root element that is one of the elements AbstractFeature, Dictionary or TopoComplex, specified in the GML schema or any element of a substitution group of any of these elements.

[ISO 19136:2007]

4.7
GML schema
Schema components in the XML namespace — as specified in OGC GML 3.3

[ISO 19136:2007]

4.8
measurement
Set of operations having the objective of determining the value of a quantity.

[ISO/TS 19101-2:2008, definition 4.20]

4.9
observation
Act of observing a property.

NOTE: The goal of an observation may be to measure or otherwise determine the value of a property.

[ISO 19156:2011 definition 4.10]

4.10
observation procedure
Method, algorithm or instrument, or system which may be used in making an observation.

[ISO19156, definition 4.11]

4.11
observation result
Estimate of the value of a property determined through a known procedure.

[ISO 19156:2011]

4.12
property <General Feature Model>
Facet or attribute of an object referenced by a name.

EXAMPLE: Abby's car has the colour red, where "colour red" is a property of the car instance.

4.13
sampled feature
The real-world domain feature of interest, such as a geological unit or structure which is observed.

[ISO 19156:2011]

4.14
sampling feature
Feature, such as a station, outcrop, borehole, section or specimen, which is involved in making observations of a domain feature.

NOTE: A sampling feature is purely an artefact of the observational strategy, and has no significance independent of the observational campaign.

[ISO 19156:2011, definition 4.16]

4.15
schema <XML Schema>
XML document containing a collection of schema component definitions and declarations within the same target namespace.

Example Schema components of W3C XML Schema are types, elements, attributes, groups, etc.

NOTE: The W3C XML Schema provides an XML interchange format for schema information. A single schema document provides descriptions of components associated with a single XML namespace, but several documents may describe components in the same schema, i.e. the same target namespace.

[ISO 19136:2007]

5. GeoSciML Models

The GeoSciML 4.1 is an ISO General Feature Model (ISO19101, ISO19109) implementation of portions of the North American Data Model [12] and CSIRO's XMML model. GeoSciML also provides models for concepts at the immediate periphery of geological mapping, such as boreholes, geologic specimens and laboratory analysis, modelled as `SF_SamplingFeatures` and `OM_Observations` (OGC 10-004r3).

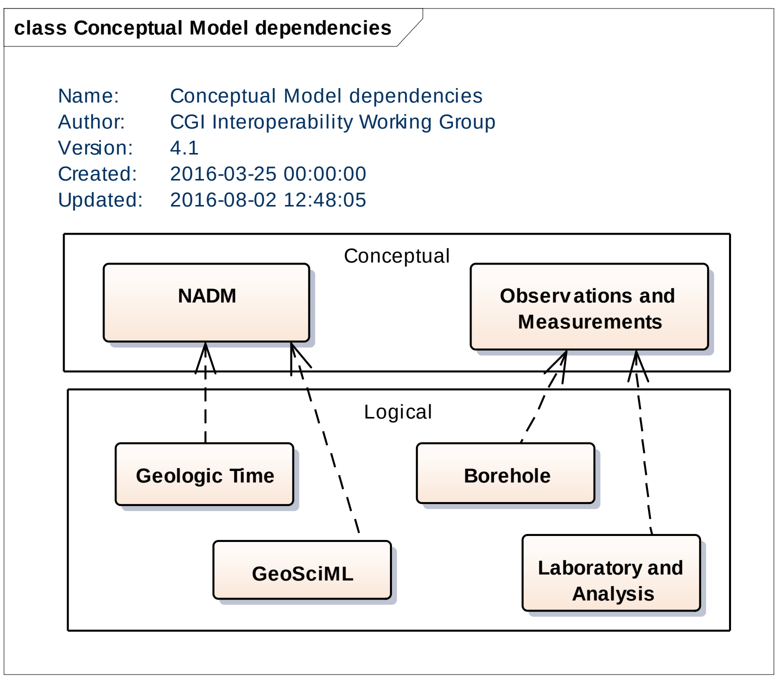


Figure 1 - Model lineage. Geological entities are logical implementations of NADM while sampling and observations entities are implementations of O&M (ISO19156).

GeoSciML has been through 4 major releases and a few minor releases since 2005. Each version brought a different interpretation of what is essentially the same conceptual model. The reader looking at all iterations will see, with few exceptions, the same concepts, the same associations and the same properties, but packaged differently. GeoSciML increasingly adopted other domain models as it evolved; it replaced XMML (eXploration and Mining Markup Languages, developed by CSIRO) by Observations and Measurements (ISO19156), custom data types for ranges and categories by SWE Common, and removed custom vocabularies to use web resources.

This fourth iteration is essentially a repackaging of the previous version 3.2 from 13 packages organised by themes into 6 packages organised by use cases (Figure 2):

- **GeoSciML Basic**: a set of core geologic features, aligned to the INSPIRE Data Specification on Geology.
- **GeoSciML Extension**: an extension providing detailed description of basic features which adds additional properties and associations.
- **GeoSciML Geologic Age**: a model for the representation of geologic time using procedures adopted by the International Stratigraphic Commission.
- **GeoSciML Borehole**: a model for boreholes, including geologic logs and drilling details and other engineering information.
- **GeoSciML Laboratory and Analysis**: a model for laboratory analytical metadata, geological sampling and specimens, and isotopic age observation results.
- **GeoSciML Lite**: previously known as "GeoSciML Portrayal" in version 3.2; a simplified alternate implementation of the conceptual model for layer based applications.

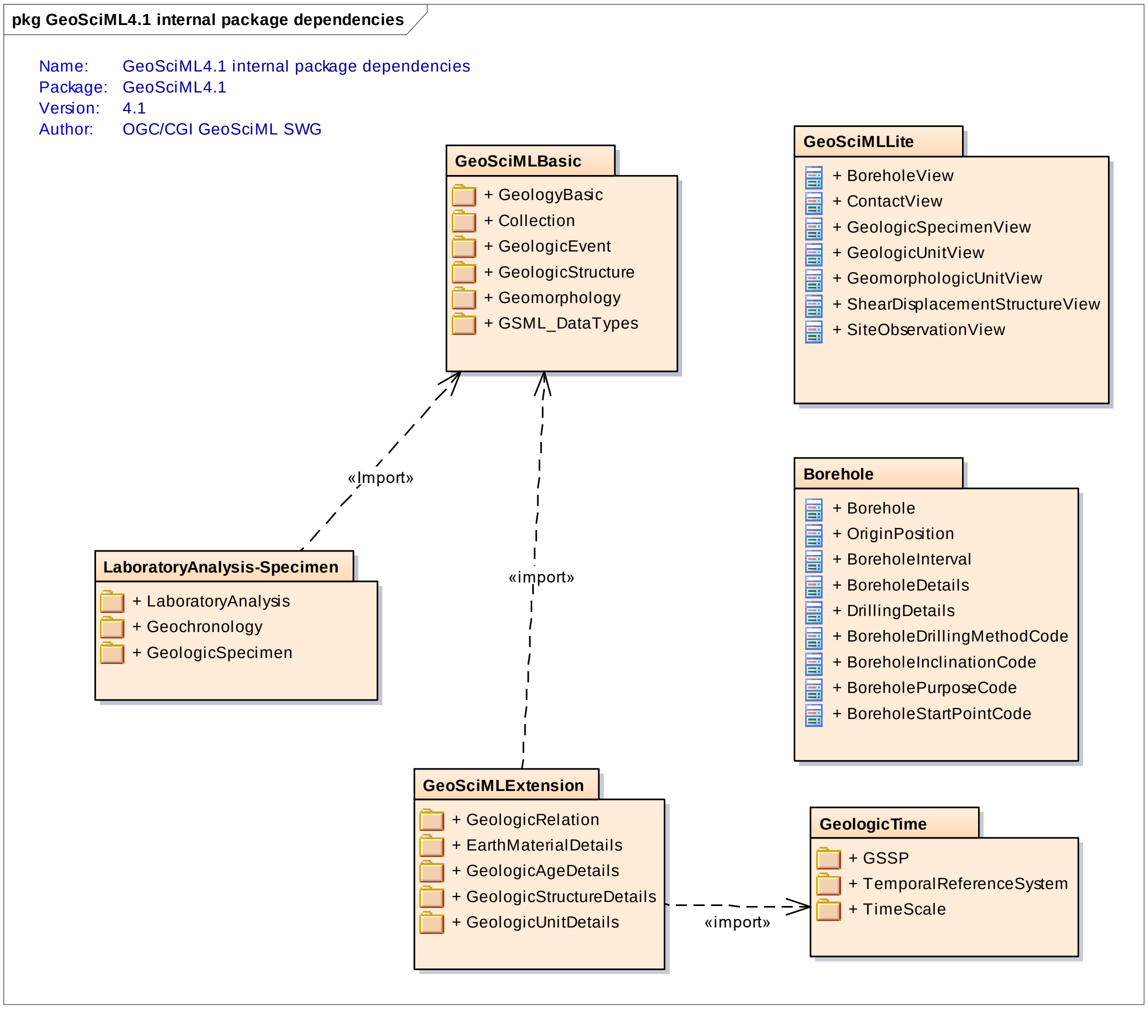


Figure 2 - GeoSciML 4.1 packages.

Each application package is the subject of at least one requirements class (to conform to the modular specification) per target implementation (this specification has three targets; logical model, encoding and data instance). More target implementations might be published as separate documents.

5.1 GeoSciML Basic and Extension

GeoSciML describes geological features from the mapping perspective, articulated around the concept of a `MappedFeature` – the cartographic element shown on a map, and the `GeologicFeature` it represents. All geologic concepts that can be represented on a map are subtypes of `GeologicFeature`.

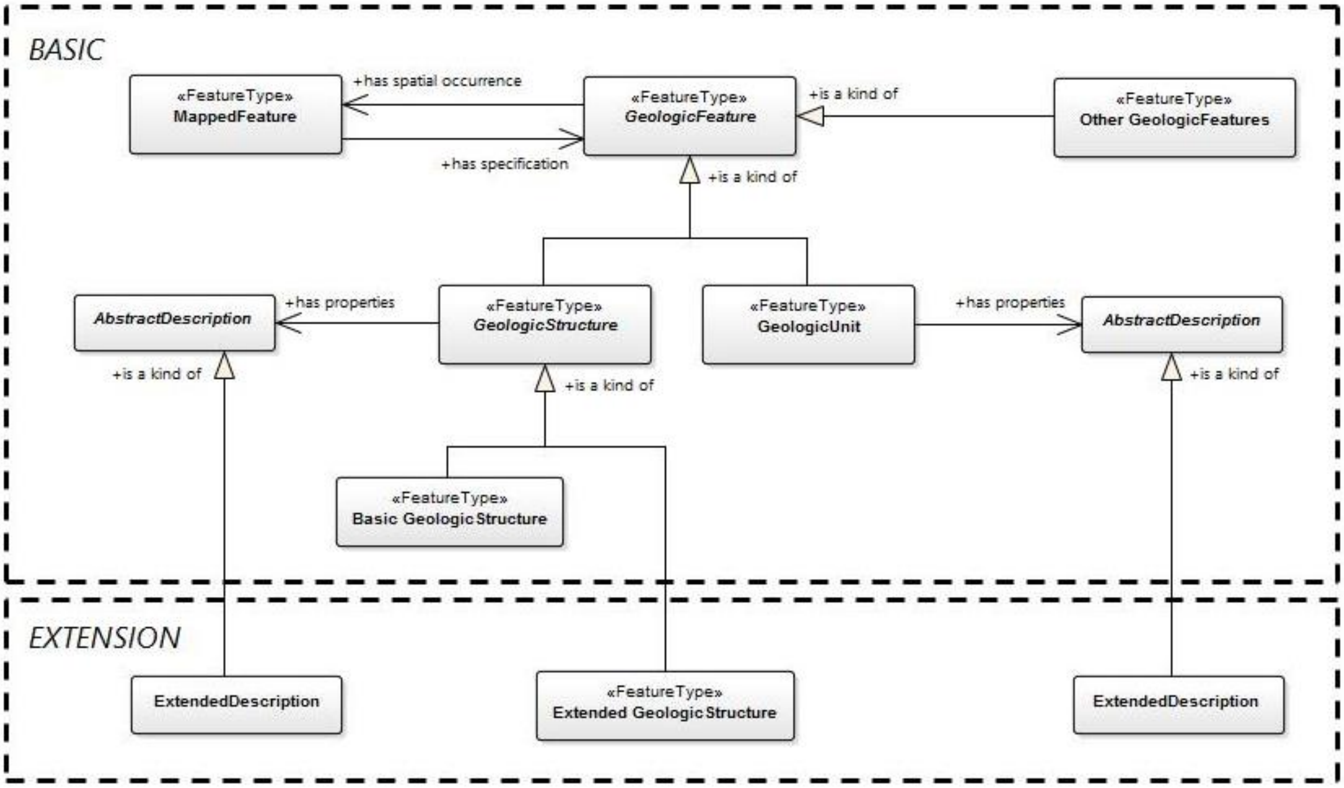


Figure 3 - High-level model.

GeologicFeature is an abstract class materialised into four concrete classes (Figure 4) - GeologicEvent, GeologicStructure, GeologicUnit and GeomorphologicFeature. The other main features of the GeoSciML model are not geologic features themselves, but features related to the activity of sampling and observing geology (such as Borehole or GeologicSpecimen) and are therefore modelled as SF_SamplingFeature (O&M) subtypes.

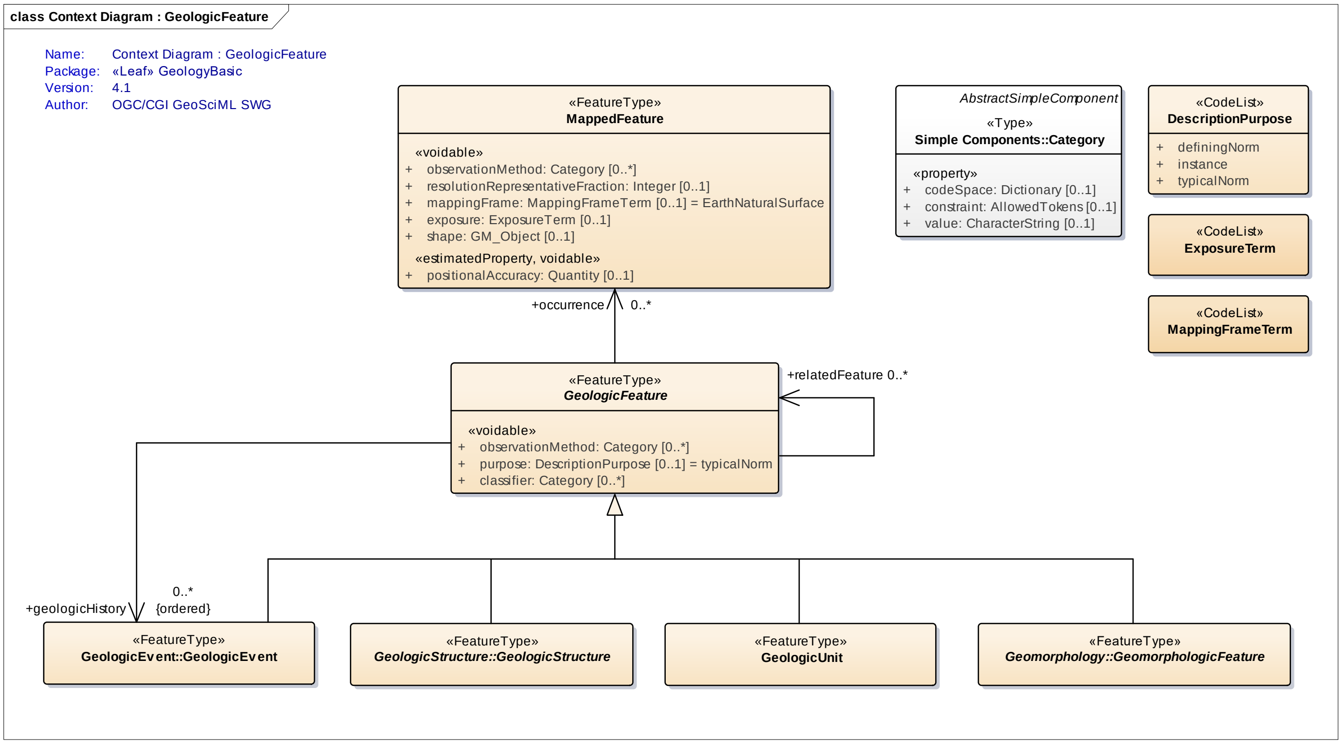


Figure 4 - Core feature model for GeoSciML.

`GeologicFeature` can share arbitrary relationships through a relation class (`AbstractRelation`), subtyped into different kind of relationships, providing distinct properties and constraints.

In order to provide a simple entry level model for data providers, but also to align to INSPIRE, only a minimal set of properties are supported by the *basic* package. When more properties are required, the data provider can use the *extension* package. To split properties between *basic* and *extension*, a modelling pattern has been adopted to overcome the limitations of classical object oriented subtyping imposed by UML and XSD.

5.1.1 **AbstractDescription classes**

The technique to add extended properties to an existing class is normally to create a subtype to carry the new properties (Fig. 5).

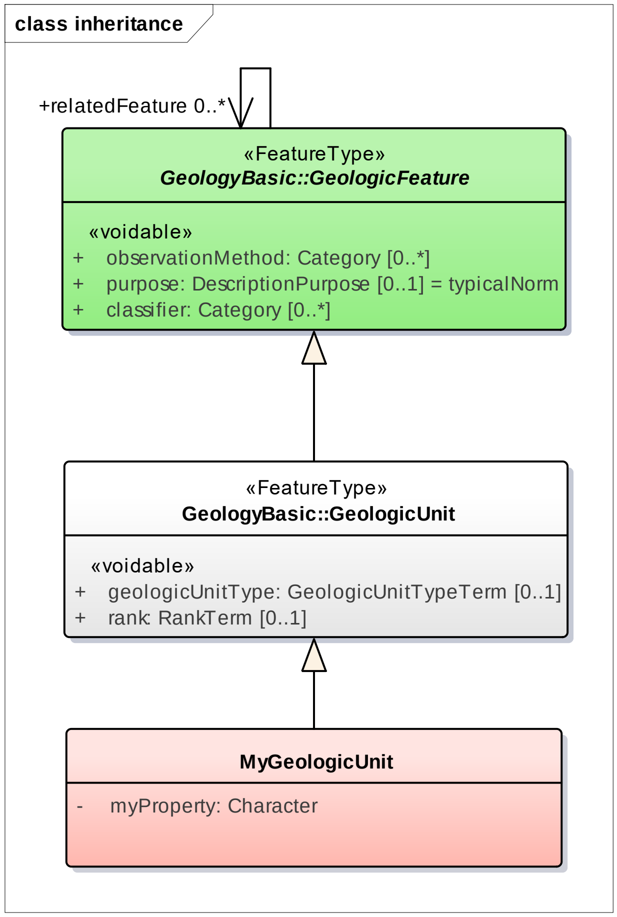


Figure 5 - Adding properties by extension.

But this only works when properties need to be added to a leaf class. Properties added by subtyping a class higher up in the chain of inheritance will create a new branch, and new properties won't propagate to existing subtypes in the main branch. GeoSciML 4 adopts an extension pattern using abstract property blocks or 'AbstractDescription' classes (Fig. 6). Blocks of extended properties are organized in their own Datatype, subtyping `AbstractDescription`.

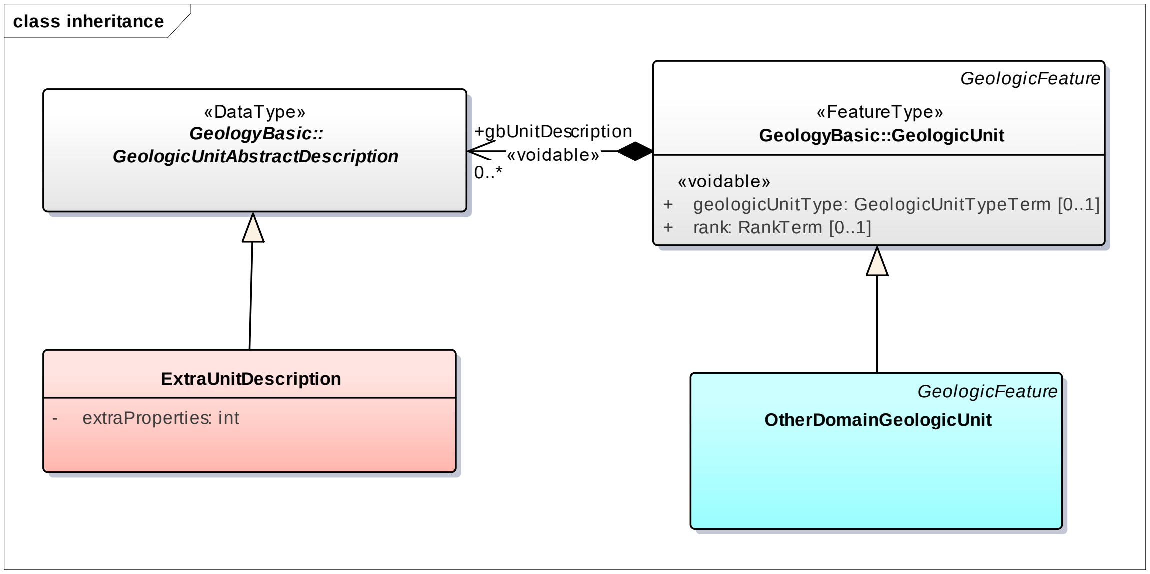


Figure 6 - Extension pattern using a property block (AbstractDescription class).

This pattern has two main advantages:

- It does not require the creation of a new feature type to add properties to core features.
- Extra properties can be defined and used by other user communities (e.g., properties added by a geophysical application could be reused by groundwater applications).

GeoSciML Basic contains nine stub AbstractDescription classes ultimately materialised in GeoSciML Extension (Table 1).

Table 1 - GeoSciML Basic stub AbstractDescription classes.

Class	Description
AbstractFeatureRelation	Association class placeholder to describe relations between geologic features.
EarthMaterialAbstractDescription	Detailed earth material description placeholder for GeologicUnit and EarthMaterial.
GeologicUnitAbstractDescription	Detailed description placeholder for GeologicUnit.
GeologicEventAbstractDescription	Detailed description placeholder for GeologicEvent.
ContactAbstractDescription	Detailed description placeholder for Contact.
FoliationAbstractDescription	Detailed description placeholder for Foliation.
FoldAbstractDescription	Detailed description placeholder for Fold.

ShearDisplacementStructureAbstractDescription	Detailed description placeholder for ShearDisplacementStructure.
GeomorphologicUnitAbstractDescription	Detailed description placeholder for GeomorphologicUnit.

Since those classes are abstract in GeoSciML Basic, data providers need to implement GeoSciML Extension, or any third party extension to get concrete classes.

This modelling pattern is also used by other standards communities (e.g., ISO 19115-3).

5.2 GeoSciML Lite

GeoSciML Lite is a denormalised view, or a transformation, of key geological and sampling features, designed as a simple entry-level model to publish datasets, particularly adapted to geographic visualization with key reporting properties. The use case for GeoSciML Lite is a simple layer-based application; such as web map application or GIS where the key functionality is to display a map layer and perform simple identify or query operations. The classes are modelled to be easily implementable in any GIS or web mapping application. One feature type maps to one table composed of optional, single-occurrence properties – consistent with the structure of denormalised RDBMS tables. The XML implementation (clause 9.8) is conformant with GML Simple Feature (OGC 10-100r3).

Each property of GeoSciML Lite classes is derived from a subset of the properties available in the full GeoSciML model, with the exception of "genericSymbolizer", which is a convenience property providing a cartographic symbol or code. The property is a shortcut to symbolisation that would otherwise be provided by an SLD (Styled Layer Descriptor).

Some fields are external references, in the form of HTTP URI, to provide hyperlinks for applications to access linked data definitions to externally governed vocabulary terms and/or complex representations of the features when required.

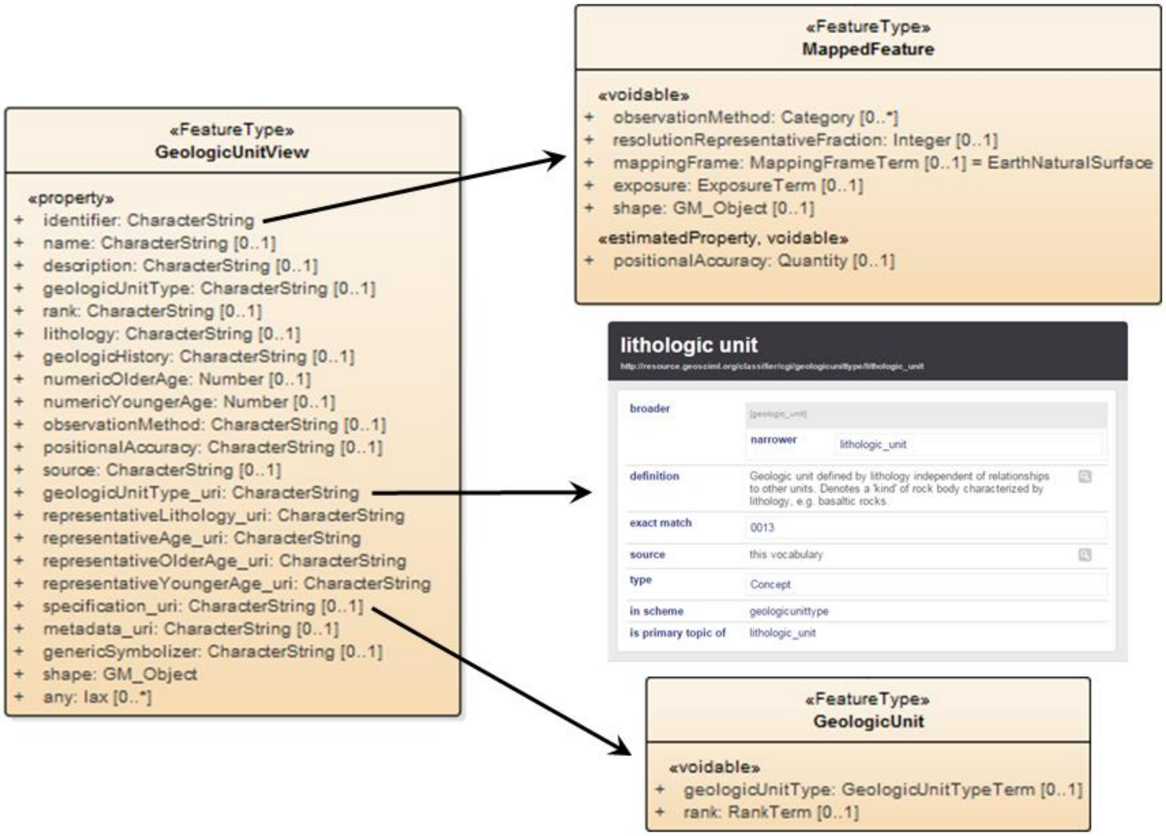


Figure 7 - Example of linkage between a GeoSciML Lite feature and other GeoSciML packages and vocabulary term URI's. An instance of GeologicUnitView matches an instance of MappedFeature.

6. Conventions

6.1 Requirement class

Each normative statement (requirement or recommendation) in this specification is a member of a requirements class. Each requirements class is described in a discrete clause or sub-clause, and summarized using the following template:

Requirements class	**/req/{classM}**
Target type	[artefact or technology type]
Dependency	[identifier for another requirements class]
Requirement	/req/{classM}/{reqN}

Recommendation	/req/{classM}/{recO}
Requirement	/req/{classM}/{reqP}
Requirement /Recommendation	[repeat as necessary]

All requirements in a requirements class must be satisfied. Hence, the requirements class is the unit of re-use and dependency, and the value of a dependency requirement is another requirements class. All requirements in a dependency must also be satisfied by a conforming implementation. A requirements class may consist only of dependencies and introduce no new requirements.

6.2 Requirement and Recommendation

All requirements and recommendations are normative, and each is presented using the following template:

/req/[classM]/[reqN]	[Normative statement]

where /req/[classM]/[reqN] identifies the requirement or recommendation. The use of this layout convention allows the normative provisions of this specification to be easily located by implementers.

6.3 Conformance class

Conformance to this specification is possible at a number of levels, specified by conformance classes (Annex A). Each conformance class is summarized using the following template:

Conformance class	**/conf/{classM}**
Dependency	[identifier for another conformance class]
Requirements	/req/{classA}
Tests	[reference to clause(s) containing tests]

All tests in a class must be passed. Each conformance class tests conformance to a set of requirements packaged in a requirements class.

W3C Schema (XSD) and ISO Schematron (SCH) files are considered as part of this specification, although available online only, due to concerns about document size. Many requirements are expressed in a single XSD or SCH file, although tests are listed individually in the conformance annex (one test for XSD and one test for SCH).

Schematron files explicitly specify which requirements are being tested in the title of the schematron pattern.

```
<pattern id="unit-of-measure">
        <title>Test requirement: /req/gsml4xsd/unit-of-measure</title>
        <rule context="SWE::Quantity">
                <assert test="SWE::Quantity">Quantity must have a UOM</assert>
        </rule>
</pattern>
```

6.4 Identifiers

The normative provisions in this specification are denoted by a URI constructed using this pattern:

`http://www.opengis.net/spec/{standard}/{m.n}`

All requirements and conformance tests that appear in this document are denoted by a partial URI which is relative to this base. The identifier supports cross-referencing of class membership, dependencies, and links from each conformance test to the requirements tested. In this specification identifiers are expressed as partial URIs or paths, which can be appended to a base URI that identifies the specification as a whole in order to construct a complete URI for identification in an external context.

The URI for each requirements class has the form:

`http://www.opengis.net/spec/geosciml/4.1/req/[classM].`

The URI for each requirement or recommendation has the form:

`http://www.opengis.net/spec/geosciml/4.1/req/[classM]/[reqN].`

The URI for each conformance class has the form:

`http://www.opengis.net/spec/geosciml/4.1/conf/[classM].`

The URI for each conformance test has the form:

`http://www.opengis.net/spec/geosciml/4.1/conf/[classM]/[testN].`

6.5 Classifiers

This document contains a large number of references to classifiers that might sometimes be ambiguous. Classes and packages are simply referred by their name formed using "`CamelCase`" name in mono space type. Duplicate names do exist and the scope (the package of a class or the class a property belongs to) must be made explicit.

OCL syntax will be used to identify a logical model classifier from the UML model.

```
Package::{…}Package::Classifier::Property:Type
```

Package names are not formal in UML and can change from one implementation to another. The reference model used by GeoSciML, and several other domain models, is HollowWorld. For example, a complete path for a `SF_SamplingPoint` in HollowWorld (from HollowWorld root) is

```
ISO TC211::ISO 19156 All::ISO 19156:2011 Observations and
Measurements::Sampling Features::samplingPoint::SF_SamplingPoint
```

For the sake of readability, and also because some HollowWorld package names do not have OCL friendly names (e.g. some package names contain ':', as shown in the previous example), this document will use shortcuts to identify packages. For example, for `OM::SF_SamplingPoint`, OM acts as a shortcut for (`ISO TC211::ISO 19156 All::ISO 19156:2011 Observations and Measurements::*`) that includes all classifiers in all sub packages and avoids creating a shortcut for all sub packages. The list of shortcuts is provided in Section 8.1.2. GeoSciML also uses the recently published ISO19115-3 model which has numerous classifier name overlaps with ISO19115 from HollowWorld.

W3C XPath will be used in XML instances. XML entities will be identified using their full qualified name (namespace, identified by its prefix, and entity name).

- `gsmlb:GeologicUnit` refers to an instance of GeologicUnit, from namespace `xmlns:gsmlb="http://www.opengis.net/gsml/4.1/GeoSciML-Basic"`
- `gsmlb:GeologicUnit/gml:name` refers to the `name` property of `GeologicUnit`
- `gsmlb:GeologicUnit/gml:name/@codeName` refers to the `codeName` attribute of the `name` property of `GeologicUnit`

7. Conceptual Model

The strictly geological portion of GeoSciML, as opposed to the parts dealing with sampling (e.g., boreholes) and laboratory metadata, is largely an implementation of the North American Data Model [12]. NADM is a technologically neutral conceptual model that addresses geoscience concepts and the relationships between them. GeoSciML 4 does not implement NADM Geologic Portrayal (a model of cartographic elements composing a geological map, such as legends, symbols, insets, etc.) nor Geologic Vocabulary (although older versions of GeoSciML did).

GeoSciML is an ISO Feature Model implementation of NADM and this created subtle differences between NADM and GeoSciML as the logical model deals with ISO Feature Model idiosyncrasies. For instance, NADM multiple inheritances used in `Fossil` could not be implemented in the ISO world that forbids such constructs. There were also conceptual changes, especially regarding `EarthMaterial` that is not considered as a `GeologicFeature` (hence an ISO FeatureType) in GeoSciML, but as a Type.

Sampling and analytical metadata features (`Borehole` and `GeologicSpecimen` in particular) are extensions of Observations and Measurements (10-004r3) and as such implement the underlying Observations and Measurements conceptual model. `Borehole` introduces engineering concepts known to the industry without a formal conceptual model. It has been recognised that `Boreholes` are features that are common outside the geological mapping realms (like the energy and mineral resources industries, hydrogeology, civil engineering, etc) and more formal work could be carried by those interested parties. Therefore, `Borehole` in GeoSciML is a essentially placeholder waiting to be replaced by a more formal Borehole model that is applicable across more domains than geology. It is expected that the Laboratory Analysis model could also be formalised by parties interested in (geo)chemical analysis.

Requirements class	
/req/gsml4-conceptual	
Target type	Logical Model
Name	GeoSciML conceptual model
Dependency	ISO19101:2002 Reference Model Clause 7
Dependency	ISO19103 2015 Conceptual Model Language
Dependency	ISO19104:2008
Dependency	Unified Modeling Language (UML). Version 2.3. May 2010
Requirement	**/req/gsml4-conceptual/similarity** A target logical model, when claiming compliance with this conceptual model, SHALL implement its components (classes, attributes, relationships) respecting the conceptual model definitions and intent, such that high semantic similarity is obtained between the logical and conceptual model components.

Target logical models that are compliant with the conceptual model shall implement components of the conceptual model respecting their semantics, i.e. their definition and intent. In other words, the logical model must be highly semantically similar to components of the conceptual model. Semantic similarity can be tested in multiple ways, including but not limited to: (i) direct comparison of UML components, (ii) comparison after mapping components to a common expressive knowledge representation language, such as first order logic or common logic, or (iii) comparison after mapping components to a reference ontology. The target can reuse and adapt existing logical models.

/req/gsml4-conceptual/similarity	A target logical model, when claiming compliance with this conceptual model, SHALL implement its components (classes, attributes, relationships) respecting the conceptual model definitions and intent, such that high semantic similarity is obtained between the logical and conceptual model components.

8. Logical Model

This section describes requirements that must be met by all target implementations that claim conformance to this specification. The target implementation of the logical model is generally an encoding specification or a schema (which could use technologies like XSD, for example) and not a data instance. The logical model, expressed using UML, provides naming, structure and cardinality for any physical implementation. The UML model is a normative artefact as the official representation of GeoSciML. Rules that can be unambiguously inferred from the UML model will not be documented as explicit requirements. Specific encoding idiosyncrasies shall be addressed in the requirement clauses pertaining to that encoding.

The logical model contains almost no semantic requirements (i.e., vocabularies, enumerations). It is expected that users will employ controlled vocabularies of terms which are developed by user communities. The model provides mechanisms for delivering concepts from controlled vocabularies via URI's and linked data principles.

The UML model provides name, structure and cardinality for data elements composing various potential physical implementations of GeoSciML. There are formal mappings between UML and GML (ISO-19136), UML and RDF (ISO-19150) and best practices exist for mapping UML to RDBMS. Although it is assumed that UML is technologically neutral, in reality UML models always end up addressing some of the encoding specification details. The current GeoSciML UML model has been designed as a GML application according to ISO 19109 and borrows some of artefacts of GML. Several design decisions were guided by limitations of UML (e.g. single inheritance) and XSD (package dependencies artefacts) and some constraints of GML delivery using ISO19142 WFS (for instance, some XSD encodings are not queryable easily with ISO19143 FES). However, the UML model is detailed enough to constrain the main elements of any encoding; the names of entities and the cardinality of properties, the associations between entities and to some extent property types. On the other hand, some UML features do not have equivalences in certain encoding (for instance, JSON does not have a native support for namespaces or even schema).

Figure 8 shows requirements class dependencies:

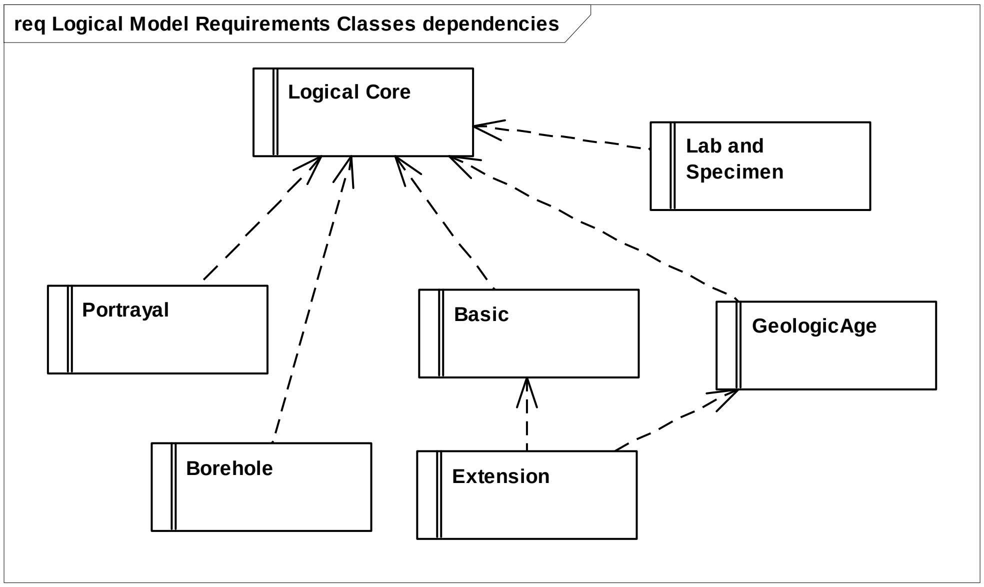


Figure 8 - Logical Model Requirements classes dependencies (external dependencies not shown)

This section defines the minimum UML mapping requirements that shall be met by any target claiming compliance to this specification.

8.1.1 Property cardinality

All properties that could feasibly be made optional are optional in GeoSciML 4.1. This is a reversal of the pattern used in GeoSciML version 3.2 where all properties were made mandatory, forcing the data provider to document why the property was missing using nillable properties. This design attracted a lot of criticism (not only for GeoSciML but for other communities confronted with the same pattern) from application developers and data providers that consider filling the instance with nil properties is “unnecessarily verbose” and a waste of bandwidth. It has been argued that nillable properties are just verbose absent values. This issue is a real concern for mobile applications where payload has an impact on user experience.

Nillable properties actually carry useful or even required information in certain use cases, such as legally bounded data exchange scenarios. Some communities using GeoSciML may still want to force usage of nillable properties and the SWG recognised that different communities might want to enforce the use of some properties for their particular needs. To meet this requirement and to offer flexibility to various communities wanting to use (or extend) GeoSciML, properties are optional, but can still be nilled. A data provider is offered two options when a value is missing:

- Omit the property
- Deliver a nilled property with relevant justification.

Which option is most useful for a community is left to that community to decide. Their decision can be enforced using Schematron. We foresee the use of a) the GeoSciML data model as defined by this specification providing naming and structure and b) a series of community-defined rules to enforce the presence of certain properties relevant to their use cases. For an XML implementation, this translates into a set of common XSD and SCH to govern conformance to GeoSciML, and community-specific SCH to enforce specific use cases, such as the INSPIRE geology specification [8].

8.1.2 Package shortcuts

The following shortcuts are used to refer to external (non GeoSciML) classifiers.

Shortcut	Full path (HollowWorld)
OM	ISO TC211/ISO 19156 All/ISO 19156:2011 Observations and Measurements
SWE	OGC/Sensor Web Enablement 2.0/SWE Common Data Model 2.0
GEO	ISO TC211/ISO 19107 All/ISO 19107:2003 Spatial Schema
Primitive	ISO TC211/ISO 19103 All/ISO 19103:2005 Conceptual schema language
Temporal	ISO TC211/ISO 19108 All/ISO 19108:2006 Temporal Schema
GML	ISO TC211/ISO 19136:2007 GML

8.2 GeoSciML Core Abstract Requirements Class (Normative)

Abstract Requirements Class	
/req/gsml4-core	
Target type	Encoding
Dependency	ISO19103:2005 Conceptual Schema Language
Dependency	ISO19107:2003 Spatial Schema
Dependency	ISO19109:2015 Rules for application schemas
Dependency	RFC 3986 Uniform Resource Identifier (URI): Generic Syntax
Dependency	ISO19115-3 Metadata
Requirement	**/req/gsml4-core/uml-entity-name** When the target implementation allows it, the exact name of the classifier SHALL be used.
Requirement	**/req/gsml4-core/uml-cardinality**

	If the target implementation allows it, it SHALL implement the same cardinality of properties and associations as defined in the UML.
Requirement	**/req/gsml4-core/uml-abstract** Abstract classes SHALL NOT be materialised.
Requirement	**/req/gsml4-core/uml-polymorphism** A target implementation SHALL implement type substitutions inferred from the UML model.
Requirement	**/req/gsml4-core/quantities-uom** Quantities and measurements SHALL have explicit units of measure from a governed ontology.
Requirement	**/req/gsml4-core/quantities-single-range** QuantityRange properties that must report a single value SHALL assign both lower and upper value as equal to that single value.
Requirement	**/req/gsml4-core/codelist** Empty classes with stereotype <<CodeList>> SHALL be implemented as externally governed vocabularies which terms are encoded as URI (RFC 3986).

This section presents requirements to which all target encodings must conform in to order to claim compliance to GeoSciML 4.1.

8.2.1 Naming of entities

/req/gsml4-core/uml-entity-name	When the target implementation allows it, the exact name of the classifier SHALL be used.

If a target implementation is capable of encoding all the artefacts (classes and properties) using the same names used in UML, it shall do so. Some target implementations might prevent it; for example, dBase (DBF files) column names are restricted to 10 characters or some RDBMS limits the use of camel case names. But if the target allows it, the exact names shall be used.

8.2.2 Cardinality

/req/gsml4-core/uml-cardinality	If the target implementation allows it, it SHALL implement the same cardinality of properties and associations as defined in the UML.

Cardinality shall be the same as defined in UML model. Since essentially all properties are optional, this clause addresses the upper bounds of cardinality: “1” or “many” in almost all cases. Therefore, if the UML model limits a property’s maximum cardinality to “1”, then the target implementation cardinality cannot be “many”.

8.2.3 Abstract classes

/req/gsml4-core/uml-abstract	Abstract classes SHALL NOT be materialised.

Not all physical implementations support the concept of an abstract class, or even inheritance and polymorphism. XSD does support that concept and all its implications, but JSON does not – although JavaScript can somewhat. This requirement specifies that the encoding specification shall not allow materialisation of an instance of a class stereotyped as abstract.

8.2.4 Polymorphism

/req/gsml4-core/uml-polymorphism	A target implementation SHALL implement type substitutions inferred from the UML model.

The type hierarchy of the UML model implies type substitutions for property values. For instance, a property value of type GeologicEvent can be substituted by a value of type DisplacementEvent because DisplacementEvent is a subtype of `GeologicEvent`. Many property types are abstract types and only a concrete subtype may be materialised (as per **/req/gsml4-core/uml-abstract**). A target implementation shall consider type substitutions using mechanisms available for this implementation.

8.2.5 Quantities

/req/gsml4-core/quantities-uom	Quantities and measurements SHALL have explicit units of measure from a governed ontology.

The quantities and measurements units of measure shall be taken from a standard vocabulary governed by an appropriate community, for example the Unified Code for Units of Measure (UCUM).

8.2.6 QuantityRange

A `QuantityRange` is a quantity formed of a lower and upper value forming a range of values. If a single value needs to be represented as a `QuantityRange`, where the single value is assigned to both lower and upper properties.

/req/gsml4-core/quantities-single-range	QuantityRange properties that must report a single value SHALL assign both lower and upper value as equal to that single value.

8.2.7 **Code lists**

/req/gsml4-core/codelist	Empty classes with stereotype <<CodeList>> SHALL be implemented as externally governed vocabularies which terms are encoded as URI (RFC 3986).

All properties that require formal vocabularies are modelled in the UML as classes having the stereotype `<<CodeList>>`. The list of valid terms is either prescribed by this specification, with a list of possible entries (Figure 9) or open (i.e., without any terms).

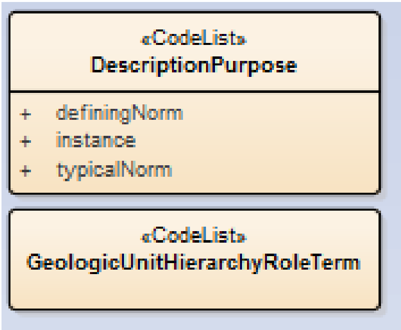


Figure 9 - Example CodeLists, with a) a prescribed list of terms (DescriptionPurpose) and b) "open" with no prescribed terms (GeologicUnitHierarchyRoleTerm)

When the list is open, the vocabulary is managed externally over the web where each vocabulary term should be encoded as a resource. Vocabulary term identifiers are URIs representing concepts from a standard vocabulary governed by an appropriate community - for example, the IUGS CGI Geoscience Terminology Working Group (http://www.cgi-iugs.org/tech_collaboration/geoscience_terminology_working_group.html and http://resource.geosciml.org) or INSPIRE [8].

This requirement does not require that URIs be actually dereferenceable, but just that a vocabulary term is associated with a syntactically correct URI.

8.3 Linked Open Data Requirements Class (Normative)

Requirements Class	
/req/gsml4-lob	
Target type	Encoding
Dependency	/req/gsml4-core
Dependency	URI
Dependency	HTTP
Requirement	**/req/gsml4-lod/codelistURI** URI used for vocabulary terms SHALL be dereferenceable to one or more representations of the vocabulary term.

Requirement	**/req/gsml4-lod/identifier** HTTP URI used as entity identifiers SHALL be to one or more representations of that entity.
Recommendation	**/req/gsml4-lod/gsml-representation** Dereferenceable HTTP URI used as identifiers SHOULD provide GeoSciML 4.1 as one of its representations.
Requirement	**/req/gsml4-lod/byref** External references to an entity conforming to [/req/gsml4-lod/identifier] shall be expressed using this entity identifier.

Although OGC standards are not restricted to a web environment, it is strongly influenced by this environment. GeoSciML was originally developed specifically for XML, but many other encodings are suitable hypermedia formats (RDF/XML, JSON-LD, HTML). This requirements class describes extra rules that shall be implemented to turn GeoSciML data instances into hypermedia compatible with Linked Open Data principles.

Linked Open Data is a method to publish structured data on the web. It leverages existing web technologies such as HTTP (transfer protocol) and URI (addressing over the web) to connect structured resources. The principle is similar to interconnected web pages through hyperlinks, except that pages are replace with structured information that can be processed by machines.

The following requirements essentially impose that URI used as vocabulary, identifiers and references can be "dereferenced", which is "*The act of retrieving a representation of a resource identified by a URI*"[2] from the web. A resource can have multiple representations (GML, XML, RDF, etc.) and this specification does not impose a particular one, although it is common sense in this context to provide a GeoSciML representation for geological features.

It is important to note that a HTTP URI in this context is <u>both</u> an identifier and a location. The same identifier is used to refer to any number of representations. Therefore, different representations are selected through content negotiation with the server.

8.3.1 Code lists URI

/req/gsml4-lod/codelistURI	URI used for vocabulary terms SHALL be dereferenceable to one or more representations of the vocabulary term.

[2] https://www.w3.org/2001/tag/doc/httpRange-14/2007-05-31/HttpRange-14 Clause 2

The requirement described at 8.2.7 in Abstract Requirements Class demand that a vocabulary reference be encoded as a URI, but does not require that the URI actually resolve to anything (it could, but it is not required). In this class, the target must ensure that the URI used to identify vocabulary terms SHALL dereference to one or more representations of a definition of the term (eg, RDF/SKOS, HTML, GML Definition, etc.)

8.3.2 Identifier

/req/gsml4-lod/identifier	HTTP URI used as entity identifiers SHALL be to one or more representations of that entity.

This requirement demands that the target ensures that a data instance exposes a URI as a unique identifier for this feature and this identifier SHALL be dereferenceable to one or more representations of that feature.

/req/gsml4-lod/gsml-representation	Dereferenceable HTTP URI used as identifiers SHOULD provide GeoSciML 4.1 as one of its representations.

It is expected that one of the representations should be a XML (GML) or any GeoSciML compliant representations, including any profiles derived from this specification.

8.3.3 ByReference associations

/req/gsml4-lod/byref	External references to an entity conforming to [/req/gsml4-lod/identifier] shall be expressed using this entity identifier.

Serialization of a dataset will often omit the full description of a feature and replace the property value with an external reference. A reference to this feature is formed by the dereferenceable identifier described in clause 8.3.2. A client ingesting the dataset can use this reference to extract a feature representation if need be. Over the web, this reference shall be a HTTP URI that can be dereferenced to one or more representations of that feature.

8.4 GeoSciML Basic Requirements Class (Normative)

Requirements Class	
/req/gsml4-basic	
Target type	Encoding
Dependency	/req/gsml4-core
Dependency	Spatial Schema ISO19107
Dependency	Conceptual schema language ISO19103

Requirement	**/req/gsml4-basic/geologicfeature-purpose** Purpose SHALL be a value from Table 2 of clause 8.4.1.1.2.
Requirement	**/req/gsml4-basic/geologicevent-single** An individual GeologicEvent SHALL only apply to one of `DisplacementEvent`, `AlterationDescription` or `MetamorphicDescription`.
Requirement	**/req/gsml4-basic/geologicevent-non-null** Either (olderNamedAge + youngerNamedAge) or numericAge SHALL not be null.
Requirement	**/req/gsml4-basic/plane-pol-dip-az-not-null** At least one of polarity, azimuth or dip SHALL not be null.
Requirement	**/req/gsml4-basic/linear-trend-plunge-not-null** At least one of plunge or trend SHALL not be null.
Requirement	**/req/gsml4-basic/quantity-range-order** The QuantityRange lowerValue SHALL be less than or equal to the upperValue.
Requirement	**/req/gsml4-basic/quantity-range-repeat** The QuantityRange's value[0] SHALL provide the same value as lowerValue and value[1] SHALL provide the same value as upperValue.

Basic package provides a collection of classes representing fundamental geological and geomorphological features (units, structures, and events), earth materials, geologic time, and the relations between them.. It limits the number of descriptive properties to match important common use cases, including the INSPIRE geological theme specification [8].

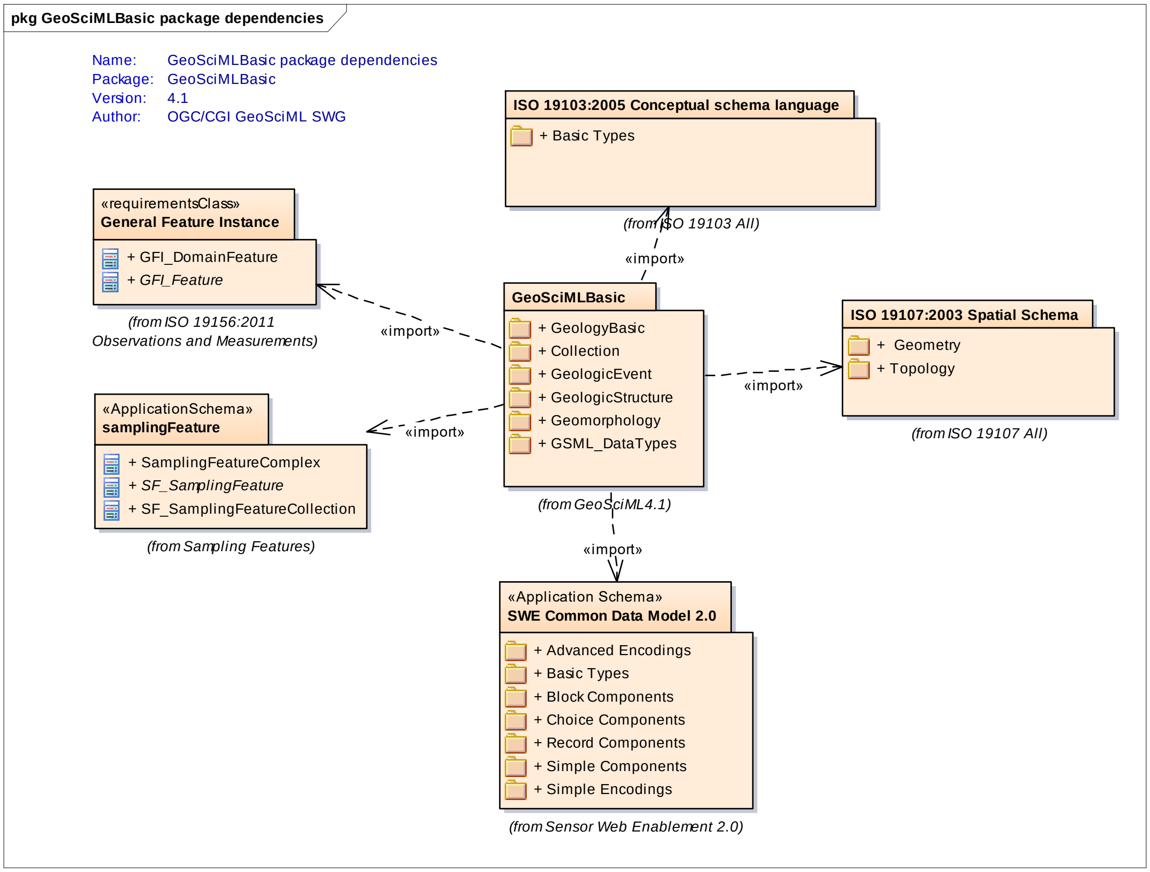


Figure 10 - GeoSciML Basic dependencies.

8.4.1 Geology Basic

GeologyBasic is a package of classes representing fundamental geological map features and the relations between them. GeoSciML describes a geologic dataset as a series of `GeologicFeature` occurrences, spatially represented as `MappedFeature`. A map is a collection of `MappedFeatures`. The term "map", typically understood as a map sheet (a given area on the surface of the earth), is only one of the possible collection of `MappedFeatures`. Other examples are cross-sections, block diagrams, and even borehole logs (a linear map). `MappedFeature` can represent any features and `GeologicFeatures` are one of the kinds of features it can represent. A `MappedFeature` identifies what it represents using its "specification" association.

Figure 11 shows the fundamental relationships between a `MappedFeature` and the `GeologicFeature`. `GeologicFeature` is further subtyped into `GeologicUnit`, `GeologicStructure`, `GeomorphologicFeature` and `GeologicEvent`.

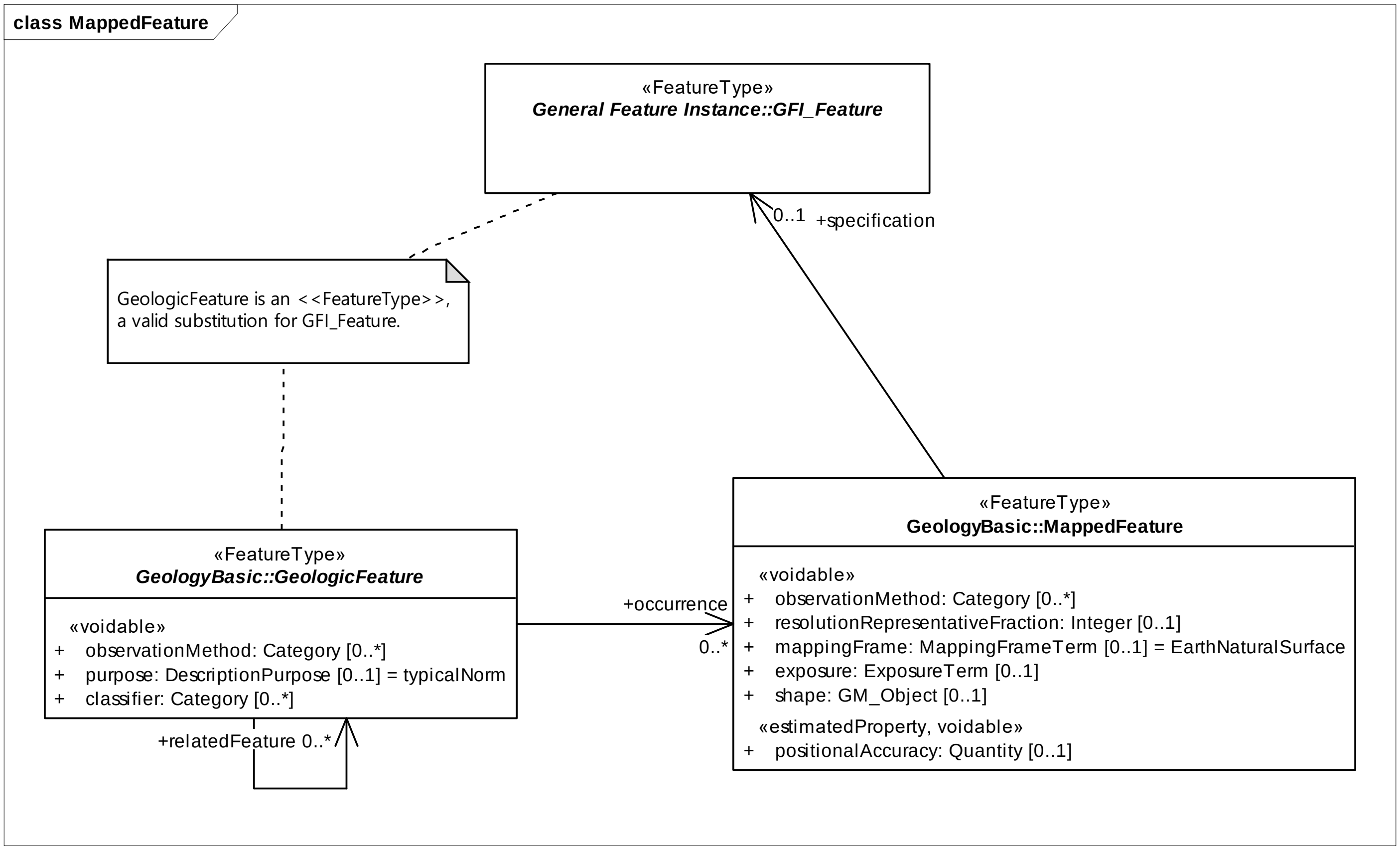


Figure 11 - Geologic Feature and MappedFeature.

8.4.1.1 GeologicFeature

The abstract `GeologicFeature` class represents a conceptual feature that is hypothesized to exist coherently in the world. It corresponds with a "legend item" from a traditional geologic map and its instance acts as the "description package". The description package is classified according to its intended purpose as a *typicalNorm*, *definingNorm or instance*. `GeologicFeature` can be used outside the context of a map (it can lack a `MappedFeature`), for example when describing typical norms (describing expected property from a feature) or defining norms (describing properties required from a feature to be classifying in a group, such as given geologic unit). A `GeologicFeature` appearing on a map is considered as an "instance".

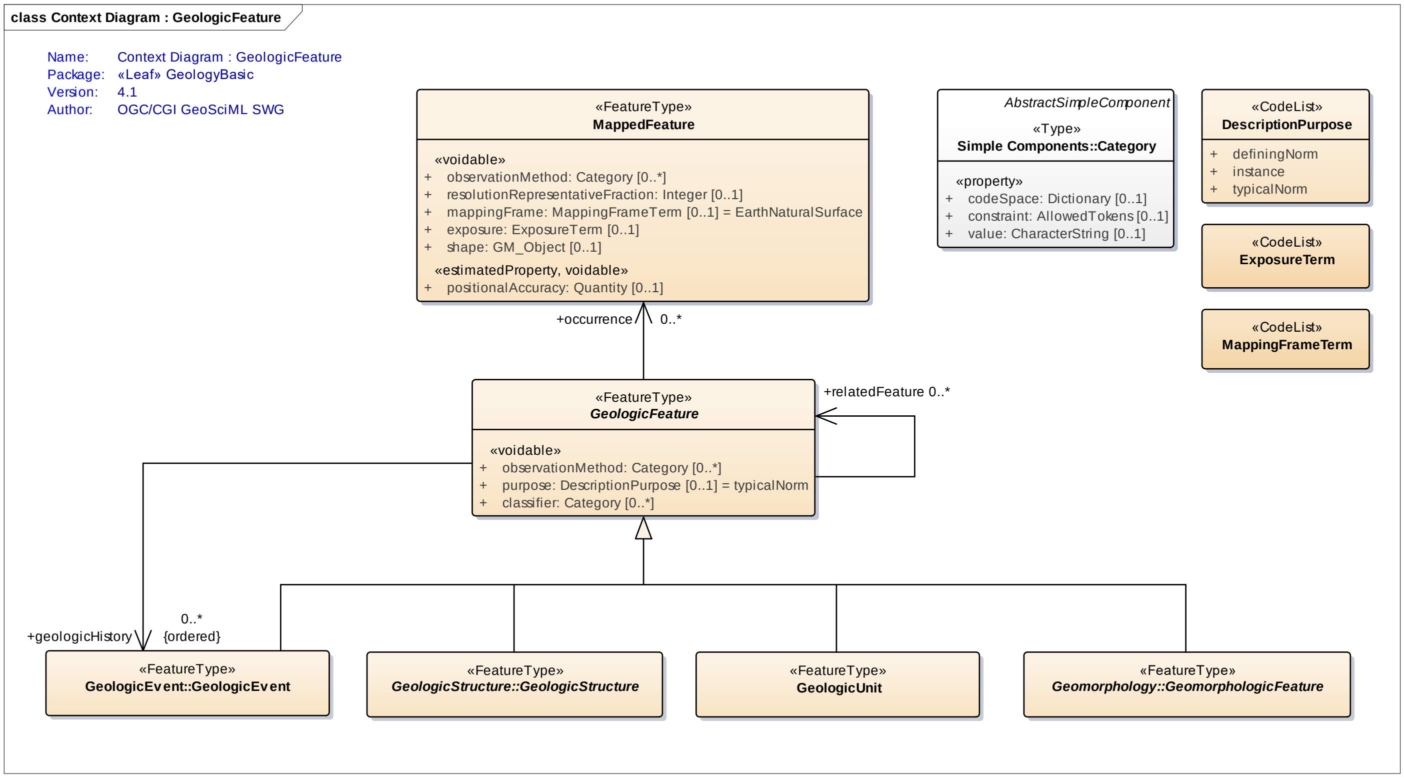


Figure 12 - Geologic Feature context diagram

8.4.1.1.1 observationMethod

The `GeologicFeature` observationMethod (`SWE::Category`) specifies the approach to acquiring the collection of attribute values that constitute an individual feature instance (e.g. point count, brunton compass on site, air photo interpretation, field observation, hand specimen, laboratory, aerial photography, creative imagination).

`ObservationMethod` is a convenience property that provides a simple approach to observation metadata when data are reported using a feature view (as opposed to observation view). This property corresponds (loosely) to ISO19115 Lineage.

8.4.1.1.2 purpose

/req/gsml4-basic/geologicfeature-purpose	Purpose SHALL be a value from Table 2 of clause 8.4.1.1.2.

The property `purpose:DescriptionPurpose` specifies the intended purpose/level of abstraction for a given feature or object instance. The possible values are: **instance**, **typicalNorm**, and **definingNorm**.

Table 2 - Valid "purpose" values

Purpose	Description
instance	And instance is 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 typicalNorm is 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.
definingNorm	A defining norm is 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.

8.4.1.1.3 classifier

The classifier (`SWE::Category`) contains a standard description or definition of the feature type (e.g., the definition of a particular geologic unit in a stratigraphic lexicon).

8.4.1.1.4 occurrence

The `occurrence` property is an association that links a notional geologic feature with any number of mapped features (`MappedFeature`). A geologic feature, such as a geologic unit may be linked to mapped features from a number of different maps.

8.4.1.1.5 geologicHistory

The geologicHistory is an association that relates one or more `GeologicEvents` to a `GeologicFeature` to describe their age or geologic history. Normally, GeoSciML uses the generic `relatedFeature::GeologicRelation` to associate `GeologicFeature` with other `GeologicFeatures`, including `GeologicEvent`. However, this design was deemed too complex for GeoSciML Basic and is therefore only available from the GeoSciML Extension package.

To avoid extra complexity, GeoSciML Basic provides an explicit geologicHistory property to associate `GeologicFeature` with a `GeologicEvent` without using a `GeologicRelation`. The consequence for someone using GeoSciML Extension is that she/he is now offered two ways to link a `GeologicFeature` and `GeologicEvent`: through `geologicHistory` and through a generic `GeologicRelation`. User communities should define a pattern that suit their needs.

8.4.1.1.6 relatedFeature (stub property)

A relatedFeature is a general structure used to define relationships between any features or objects within GeoSciML. Relationships are always binary and directional. There is always a single source and a single target for a given FeatureRelation (which is abstract in GeoSciML Basic). The relationship is always defined from the perspective of the Source and is generally an active verb.

In GeoSciML Basic, relatedFeature is a stub association (see clause 5.2).   However some encodings (such as XML) will allow a "by reference" value (for example xlink:href) to an external instance.

8.4.1.2 MappedFeature

A MappedFeature is part of a geological interpretation. It provides a link between a notional feature (description package) and one spatial representation of it, or part of it (exposures, surface traces and intercepts, etc.). The mapped features are the elements that compose a map, a cross-section, a borehole log, or any other representation. The mappingFrame identifies the domain being mapped by the geometries. For typical geological maps, the mapping frame is the surface of the earth (the 2.5D interface between the surface of the bedrock and whatever sits on it; atmosphere or overburden material for bedrock maps). It can also be abstract frames, such as the arbitrary plane that forms a mine level or a cross-section, the 3D volume enclosing an ore body or the line that approximate the path of a borehole.

The specification association identifies what notional feature is being mapped. It can be any features and is not restricted to GeoSciML feature, although it is expected to be for geological maps.

The observationMethod property (SWE::Category) contains an element in a list of categories (a controlled vocabulary) describing how the spatial extent of the mapped feature was determined.

8.4.1.2.1 positionalAccuracy

The positionalAccuracy property (SWE::Quantity) provides a quantitative value defining the radius of an uncertainty buffer around a MappedFeature (e.g., a positionalAccuracy of 100 m for a line feature defines a buffer polygon of total width 200 m centred on the line). The property is equivalent to ISO19115 DQ_PositionalAccuracy.

8.4.1.2.2 resolutionRepresentativeFraction

The property `resolutionRepresentativeFraction:Integer` is an integer value representing the denominator of the representative scale of the spatial feature. (i.e., 10000 = the spatial feature is intended to be represented at 1:10,000 scale).

8.4.1.2.3 mappingFrame

The `mappingFrame:MappingFrameTerm` provides a term from a vocabulary indicating the geometric frame on which the `MappedFeature` is projected. In most situations, mapped features are projected on the earth surface, but there are other contexts, such as a bedrock surface beneath surficial cover materials, a mine level, or a cross section.

8.4.1.2.4 exposure

The `exposure:ExposureTerm` property provides a term for the nature of the expression of the mapped feature at the earth's surface (e.g., exposed, concealed).

8.4.1.2.5 shape

The `shape:GM_Object` property contains the geometry delimiting the mapped feature. Note that while in most cases, the geometry will be a 2D polygon, it is not restricted to any dimension. For instance, a lithological log can be represented using of 1D geometries (expressed linearly from the borehole origin), or a geologic unit can be represented using a 3D volume.

8.4.1.2.6 specification

The `specification` association links an instance of `MappedFeature` to the GFI_Feature being mapped. In a geological map, MappedFeatures are used to represent GeologicFeatures, but other features from other domains could be represented.

8.4.1.3 GeologicUnit

Conceptually, a `GeologicUnit` may represent a body of material in the Earth whose complete and precise extent is inferred to exist (e.g., North American Data Model `GeologicUnit` [12], Stratigraphic unit in the sense of NACSN [14], or International Stratigraphic Code [9]), or a classifier used to characterize parts of the Earth (e.g. lithologic map unit like 'granitic rock' or 'alluvial deposit', surficial units like 'till' or 'old alluvium'). It includes both formal units (i.e. formally adopted and named in an official lexicon) and informal units (i.e. named but not promoted to a lexicon) and unnamed units (i.e., recognizable, described and delineable in the field but not otherwise formalised). In simpler terms, a geologic unit is a package of earth material (generally rock).

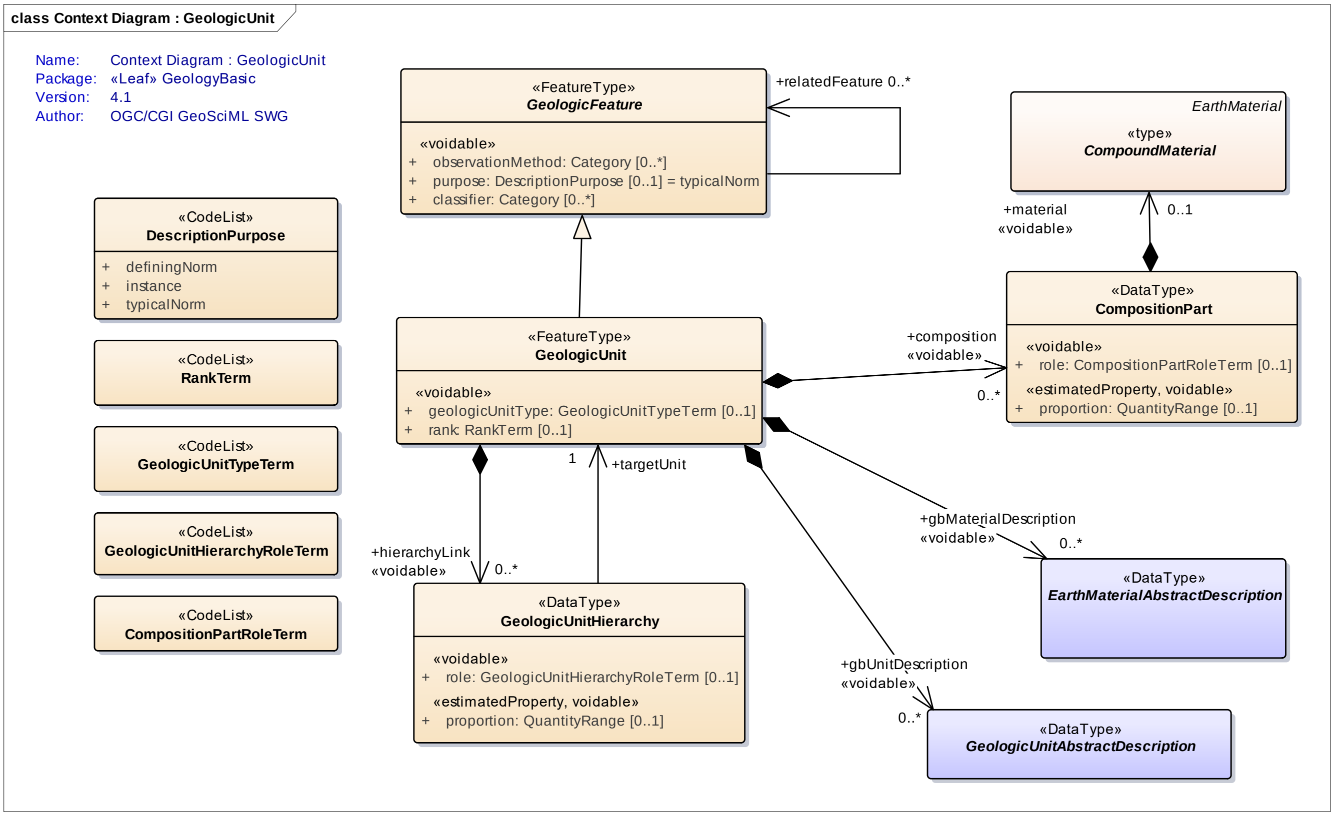


Figure 13 - GeologicUnit context diagram.

Operationally, a `GeologicUnit` is a container used to associate geologic properties with some mapped occurrence (through the `GeologicFeature::occurrence::MappedFeature` link), or with a geologic unit via a vocabulary (through the `GeologicUnit::classifier`).

Spatial properties are only available through association with a `MappedFeature` (although `GeologicUnit` do have a boundedBy property inherited from `GFI_Feature`).

8.4.1.3.1 geologicUnitType

The property `geologicUnitType:GeologicUnitTypeTerm` provides a term from a controlled vocabulary defining the type of geologic unit. Logical constraints of definition of unit and valid property cardinalities should be contained in the definition. Use of the CGI Geologic Unit Type vocabulary (e.g., http://resource.geosciml.org/classifierscheme/cgi/201211/geologicunittype) is recommended.

8.4.1.3.2 rank

The property `rank:RankTerm` contains a term that classifies the geologic unit in a generalization hierarchy from most local/smallest volume to most regional/largest.

Examples: group, subgroup, formation, member, bed, intrusion, complex, batholith

8.4.1.3.3 hierarchyLink

The property `hierarchyLink` is an association that links a `GeologicUnit` with a `GeologicUnitHierarchy` (8.4.1.4) to represent containment of a part `GeologicUnit` within another `GeologicUnit`. It indicates a subsidiary unit with its role and proportion with respect to the container unit. For example, members are described as part of formations, or different facies can be described as parts of a `GeologicUnit`.

8.4.1.3.4 composition

The property `composition` is an association that links a `GeologicUnit` with `CompositionParts` to describe the material composition of the `GeologicUnit` (e.g., a detailed, instance specific, lithologic description)

8.4.1.3.5 gbMaterialDescription (stub property)

The property `gbMaterialDescription:EarthMaterialAbstractDescription` is a placeholder that provides detailed material description. This is a stub property (See 5.1.1) in GeoSciML Basic as `EarthMaterialAbstractDescription` is abstract with subtypes defined in GeoSciML Extension.

8.4.1.3.6 gbUnitDescription (stub property)

The property `gbUnitDescription:GeologicUnitAbstractDescriptio` is a placeholder that provides detailed material description. This is a stub property (See 5.1.1) in GeoSciML Basic as `GeologicUnitAbstractDescription` is abstract with subtypes defined in GeoSciML Extension.

8.4.1.4 GeologicUnitHierarchy

`GeologicUnitHierarchy` associates a `GeologicUnit` with another `GeologicUnit` that is a proper part of that unit. Parts may be formal or notional. Formal parts refer to a specific body of rock, as in formal stratigraphic members. Notional parts refer to assemblages of particular EarthMaterials with particular internal structure, which may be repeated in various places within a unit (e.g. 'turbidite sequence', 'point bar assemblage', 'leucosome veins').

8.4.1.4.1 role

The `role:GeologicUnitHierarchyRoleTerm` property provides a term describing the nature of the parts, e.g. facies, stratigraphic, interbeds, geographic, eastern facies.

8.4.1.4.2 proportion

The `proportion` property (`SWE::QuantityRange`) provides a quantity that represents the fraction of the geologic unit formed by the part.

8.4.1.4.3 targetUnit

The property `targetUnit` is an association that specifies exactly one `GeologicUnit` that is a proper part of another `GeologicUnit`.

8.4.1.5 CompositionPart

`CompositionPart` represents the composition of a geologic unit in terms of earth material constituents (`CompoundMaterial`). It decomposes the material making of the unit into parts having distinct roles and proportions.

8.4.1.5.1 role

The property `role:CompositionPartRoleTerm` defines the relationship of the `CompoundMaterial` constituent in the geologic unit, e.g. vein, interbedded constituent, layers, dominant constituent.

8.4.1.5.2 proportion

The `proportion` property (`SWE::QuantityRange`) specifies the fraction of the geologic unit composed of the compound material.

8.4.1.5.3 Material

The `material:EarthMaterial` property contains the material description (8.4.1.6) of the composing part.

8.4.1.6 EarthMaterial

The `EarthMaterial` class holds a description of a naturally occurring substance in the Earth. `EarthMaterial` represents material composition or substance, and is thus independent of quantity or location. Ideally, `EarthMaterials` are defined strictly based on physical properties, but because of standard geological usage, genetic interpretations enter into the description as well.

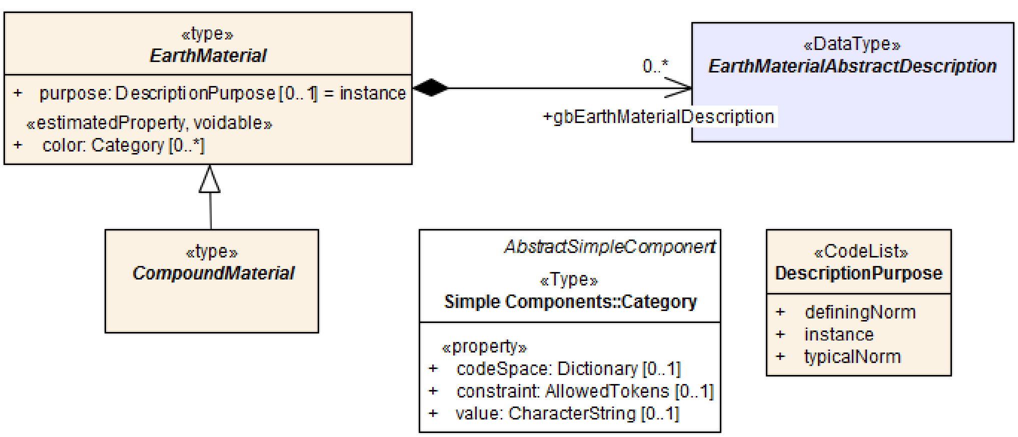


Figure 14 - EarthMaterial and related classes.

8.4.1.6.1 color

The `color` property (`SWE::Category`) is a term from a controlled vocabulary that specifies the colour of the earth material. Color schemes such as the Munsell rock and soil color schemes [11] may be used.

8.4.1.6.2 purpose

The purpose:DescriptionPurpose property provides a specification of the intended purpose or level of abstraction for the given EarthMaterial. The intent is the same a GeologicFeature's purpose (see 8.4.1.1.2) and it shares the same vocabulary (instance, typicalNorm, definingNorm).

8.4.1.6.3 gbEarthMaterialDescription (stub property)

The property gbEarthMaterialDescription:EarthMaterialAbstractDescription provides a detailed earth material description of the part. This property is a stub in GeoSciML Basic as EarthMaterialAbstractDescription is abstract with subtypes defined in GeoSciML Extension.

8.4.1.7 CompoundMaterial

A CompoundMaterial is an EarthMaterial composed of particles made of EarthMaterials, possibly including other CompoundMaterials. This class is provided primarily as an extensibility point for related domain models that wish to import and build on GeoSciML, and wish to define material types that are compound but are not rock or rock-like material. In the context of GeoSciML "RockMaterial" should be used to describe units made of rock.

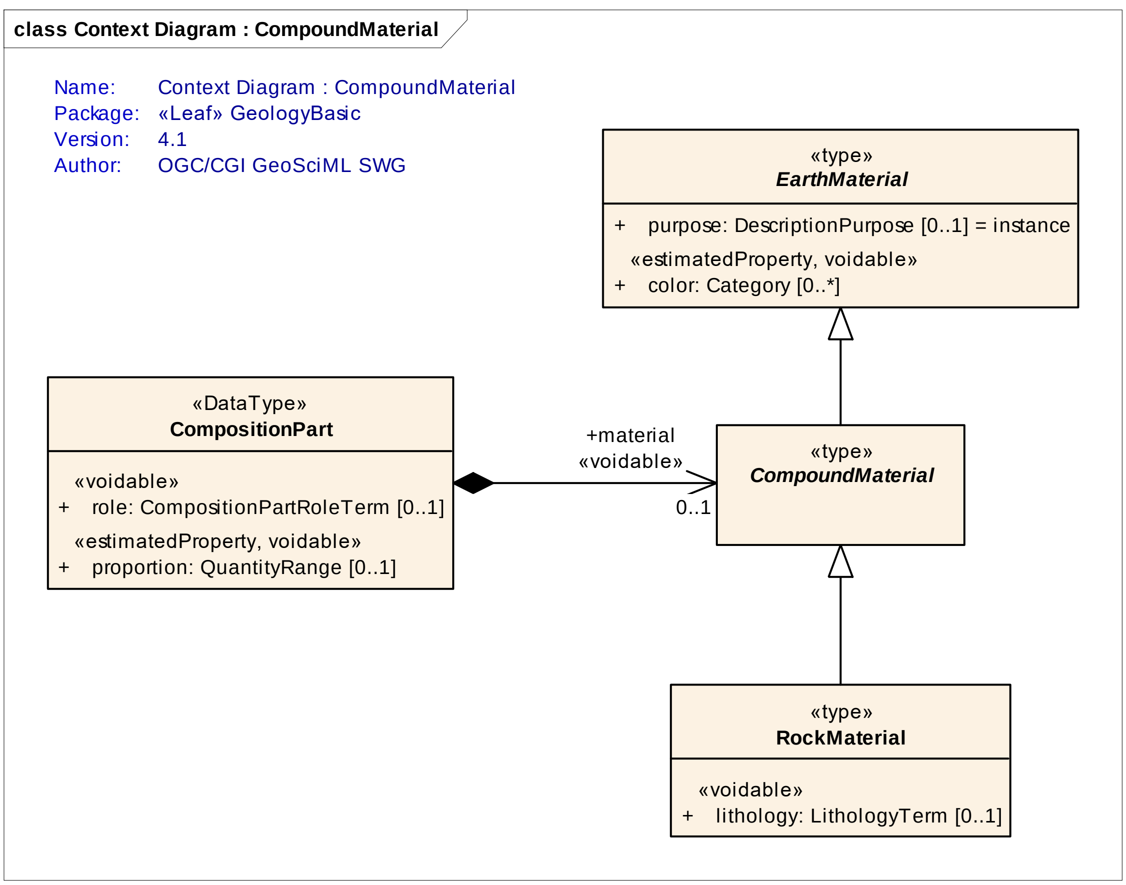


Figure 15 - Context diagram for CompoundMaterial

8.4.1.8 RockMaterial

`RockMaterial` is a specialized `CompoundMaterial` that includes consolidated and unconsolidated materials (such as surficial sediments) as well as mixtures of consolidated and unconsolidated materials. In GeoSciML Basic, Rock Material is essentially a link to a controlled vocabulary (lithology property) and a color (inherited from `EarthMaterial`). Specific material properties (and `CompoundMaterial` nesting) are available in GeoSciML Extension.

8.4.1.8.1 lithology

The `lithology:LithologyTerm` property provides a term identifying the lithology class from a controlled vocabulary.

8.4.2 Geologic Event

Geologic Event is a package of classes to describe identifiable events during which one or more geological processes act to modify geological entities. A `GeologicEvent` has a specified geologic age and may have specified environments and processes. Traditionally, geologists have described the age of a feature without explicitly specifying the event or processes the age relates to (age of a pluton is implicitly the age of the crystallisation event). The GeologicEvent class allows explicit documentation of the process and environment.

`GeologicalHistory` is an ordered aggregation of `GeologicalEvent` objects, each of which may have an associated geological age, geological environment, and one or more geological process.

The age attributes are representations of a particular geological event or feature expressed as absolute age in terms of years (`numericAge`) before present or named time periods in the geological time scale (`youngerNamedAge` and `olderNamedAge`), or by comparison with other geological events or features (relative age). An event age can represent an instant in time, an interval of time, or any combination of multiple instants or intervals.

Specifications of age in years before present are based on determination of time durations based on interpretation of isotopic analyses of `EarthMaterial` (some other methods are used for geologically young materials). Ages specified by geological time scales are essentially based on correlation of a geological unit with a standard chronostratigraphic unit that serves as a reference. Relative ages are based on relationships between geological units such as superposition, intruded by, cross-cuts, or "contains inclusions of" (a.k.a, Steno laws [17]).

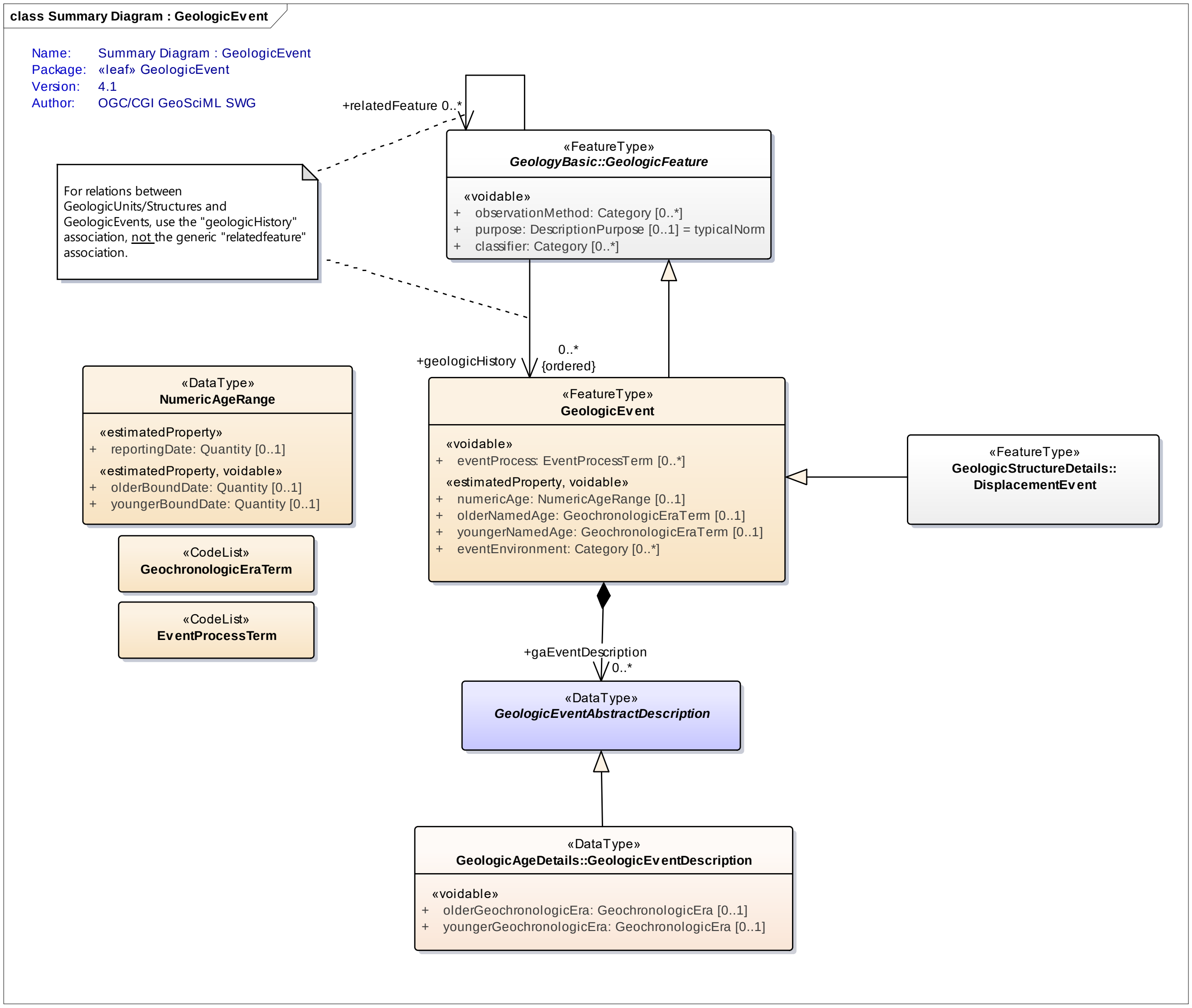


Figure 16 - Geologic Event summary diagram.

8.4.2.1 GeologicEvent

A `GeologicEvent` is an identifiable event during which one or more geological processes act to modify geological entities. It may have a specified geologic age (numeric age or `GeochronologicEraTerm`) and may have specified environments and processes. An example might be a cratonic uplift event during which erosion, sedimentation, and volcanism all take place.

Because associated processes are incompatible, a single event cannot be shared between `DisplacementEvent`, `AlterationDescription` of `MetamorphicDescription` (a process associated to `DisplacementEvent` does not apply to `AlterationDescription`).

/req/gsml4-basic/geologicevent-single	An individual event GeologicEvent SHALL only apply to one of `DisplacementEvent`, `AlterationDescription` or `MetamorphicDescription`.

A geologic event must at least have one age representation, either numerical or named.

/req/gsml4-basic/geologicevent-non-null	Either (olderNamedAge + youngerNamedAge) or numericAge SHALL not be null.

8.4.2.1.1 eventProcess

The `eventProcess:EventProcessTerm` property provides a term from a controlled vocabulary specifying the process or processes that occurred during the event. Examples include deposition, extrusion, intrusion, cooling.

8.4.2.1.2 numericAge

The `numericAge:NumericAgeRange` property provides an age in absolute year before present (BP). Present is defined by convention to be January 1st 1950 (although van der Plitch & Hogg [20], suggests this convention to be restricted to radiocarbon estimations).

8.4.2.1.3 olderNamedAge

The property `olderNamedAge:GeochronologicalEraTerm` defines the older boundary of age of an event expressed using a geochronologic era defined according to a geologic time scale as per the `GeologicTime` schema (eg, the International Commission on Stratigraphy Chronostratigraphic Chart - http://www.stratigraphy.org/index.php/ics-chart-timescale).

8.4.2.1.4 youngerNamedAge

The property `youngerNamedAge:GeochronologicalEraTerm` defines the younger boundary of age of event expressed using a geochronologic era defined according to a geologic time scale per the `GeologicTime` schema. (eg, the International Commission on Stratigraphy Chronostratigraphic Chart - http://www.stratigraphy.org/index.php/ics-chart-timescale).

8.4.2.1.5 eventEnvironment

The `eventEnvironment` property (`SWE::Category`) is a category from a controlled vocabulary identifying the physical setting within which a `GeologicEvent` takes place. Event environment is construed broadly to include physical settings on the Earth surface specified by climate, tectonics, physiography or geography, and settings in the Earth's interior specified by pressure, temperature, chemical environment, or tectonics.

8.4.2.1.6 geEventDescription (stub property)

The property `geEventDescription:GeologicEventAbstractDescription` contains a detailed event description. This is a stub property in GeoSciML Basic since

GeologicEventAbstractDescription is abstract and with subtypes defined in GeoSciML Extension.

8.4.2.2 NumericAgeRange

The NumericAgeRange class represents an absolute age assignment using numeric measurement results.

8.4.2.2.1 reportingDate

The reportingDate (SWE::Quantity) property reports a single time coordinate value to report as representative for this NumericAge assignment.

8.4.2.2.2 olderBoundDate

The olderBoundDate (SWE::Quantity) property reports the older bounding time coordinate in an age range.

8.4.2.2.3 youngerBoundDate

The youngerBoundDate (SWE::Quantity) property reports the younger bounding time coordinate in an age range.

8.4.3 **Geologic Structure**

Geologic Structure is a package of classes to describe GeologicStructures which are a configuration of matter in the Earth based on describable inhomogeneity, pattern, or fracture in an EarthMaterial. The scale of geological structures ranges from microscopic (micron-scale) to megascopic (km-scale). Examples of such inhomogeneities include fractures, mineral grain boundaries, and boundaries between parts of the rock with different particle geometry (texture) or composition.

GeologicStructure is grounded in relationships between parts of a rock or rock body. As used here, it includes sedimentary structures. The identity of a GeologicStructure is independent of the material that is the substrate for the structure although there are almost always strong dependencies between the nature of the earth material substrate and the kinds of geological structure that may be present.

A disaggregated heap of particles does not have structure, and can only be described in terms of the mineralogy and geometrical character of the constituent particles. Geologic structures are more likely to be found in, and are more persistent in, consolidated materials than in unconsolidated materials. Properties like "clast-supported", "matrix-supported", and "graded bed" that do not involve orientation are considered kinds of GeologicStructure because they depend on the configuration of parts of a rock body.

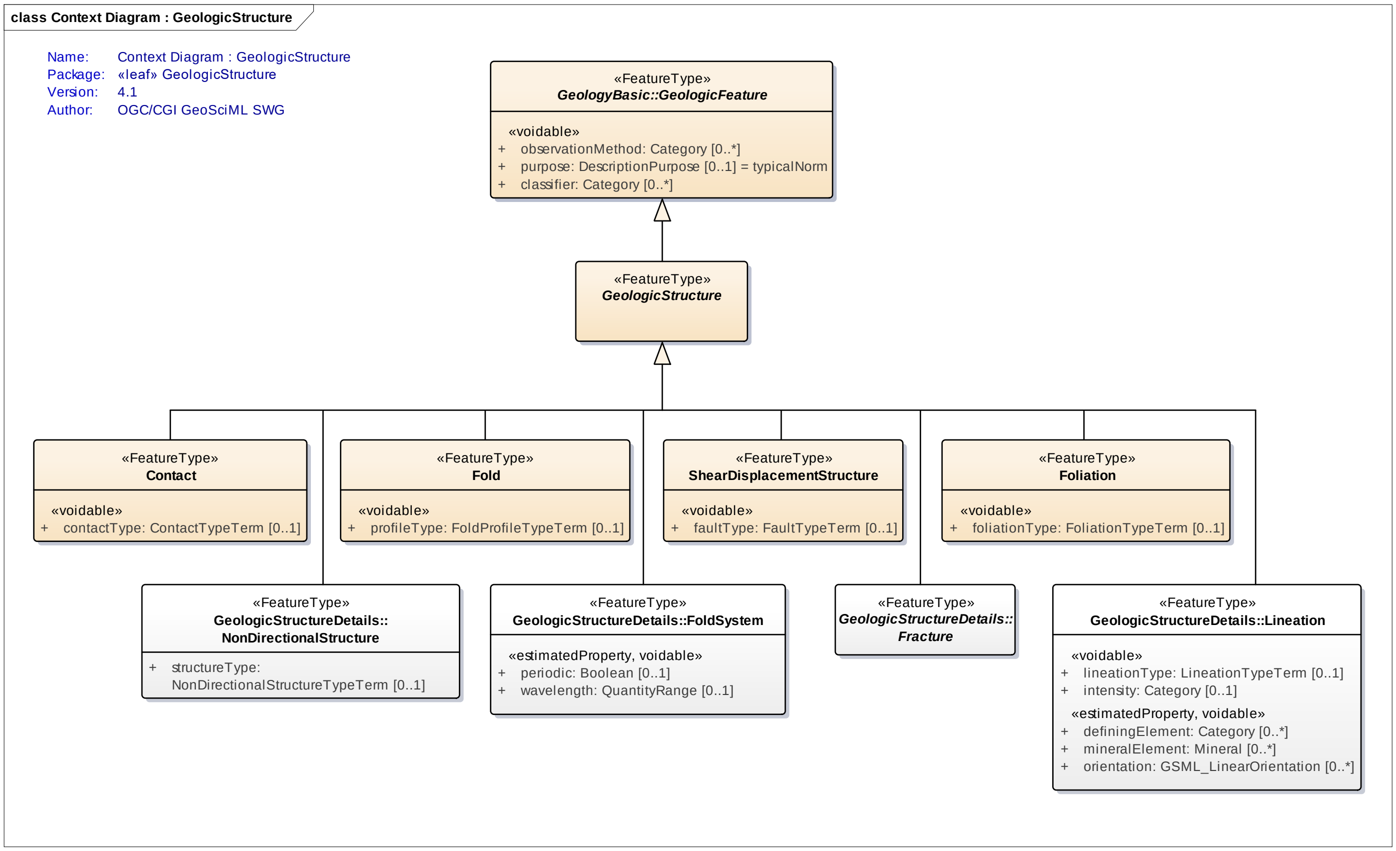


Figure 17 - Summary diagram of Geologic structures.

8.4.3.1 GeologicStructure

A geologic structure is a configuration of matter in the Earth based on describable inhomogeneity, pattern, or fracture in an earth material. The identity of a `GeologicStructure` is independent of the material that is the substrate for the structure. The general `GeologicFeatureRelation` (available in the Extension package – see 8.5) is used to associate penetrative `GeologicStructures` with `GeologicUnits`. GeoSciML Basic only provides a limited set of core structures (`Contact`, `Fold`, `ShearDisplacementStructure` and `Foliation`) with a single property to categorise them. Supplemental properties (through the pattern described in 5.1.1) and geologic structure types are available from the Extension package.

8.4.3.2 Contact

A contact is a general concept representing any kind of surface separating two geologic units, including primary boundaries such as depositional contacts, all kinds of unconformities, intrusive contacts, and gradational contacts, as well as faults that separate geologic units.

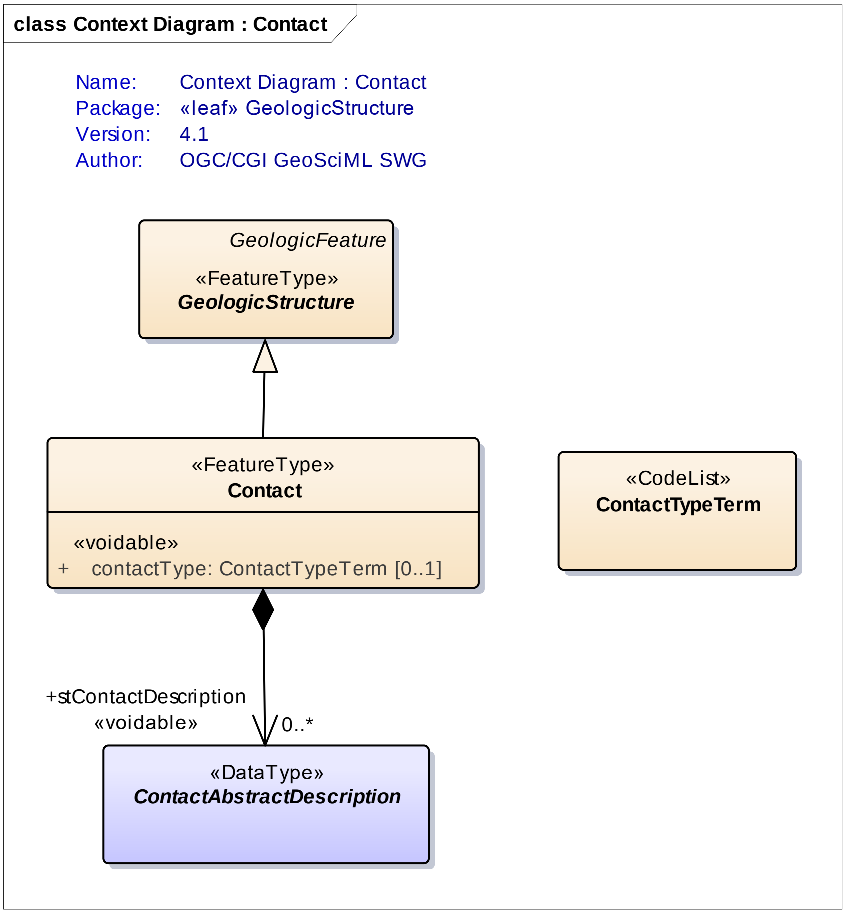


Figure 18 - Contact context diagram

8.4.3.2.1 contactType

The property `contactType:ContactTypeTerm` classifies the contact (e.g. intrusive, unconformity, bedding surface, lithologic boundary, phase boundary) and is a term from a controlled vocabulary.

8.4.3.2.2 stContactDescription (stub property)

The property `stContactDescription:ContactAbstractDescription` provides a detailed contact description. This is a stub property in GeoSciML Basic since `ContactAbstractDescription` is an abstract class with subtypes defined in GeoSciML Extension.

8.4.3.3 Fold

A fold is formed by one or more systematically curved layers, surfaces, or lines in a rock body. A fold denotes a structure formed by the deformation of a geologic structure, such as a contact which the original undeformed geometry is presumed, to form a structure that may be described by the translation of an abstract line (the fold axis) parallel to itself along some curvilinear path (the fold profile). Folds have a hinge zone (zone of maximum curvature along the surface) and limbs (parts of the deformed surface not in the hinge zone). Folds are described by an axial surface, hinge line, profile geometry, the solid angle between the limbs, and the relationships between adjacent folded surfaces if the folded structure is a Layering fabric.

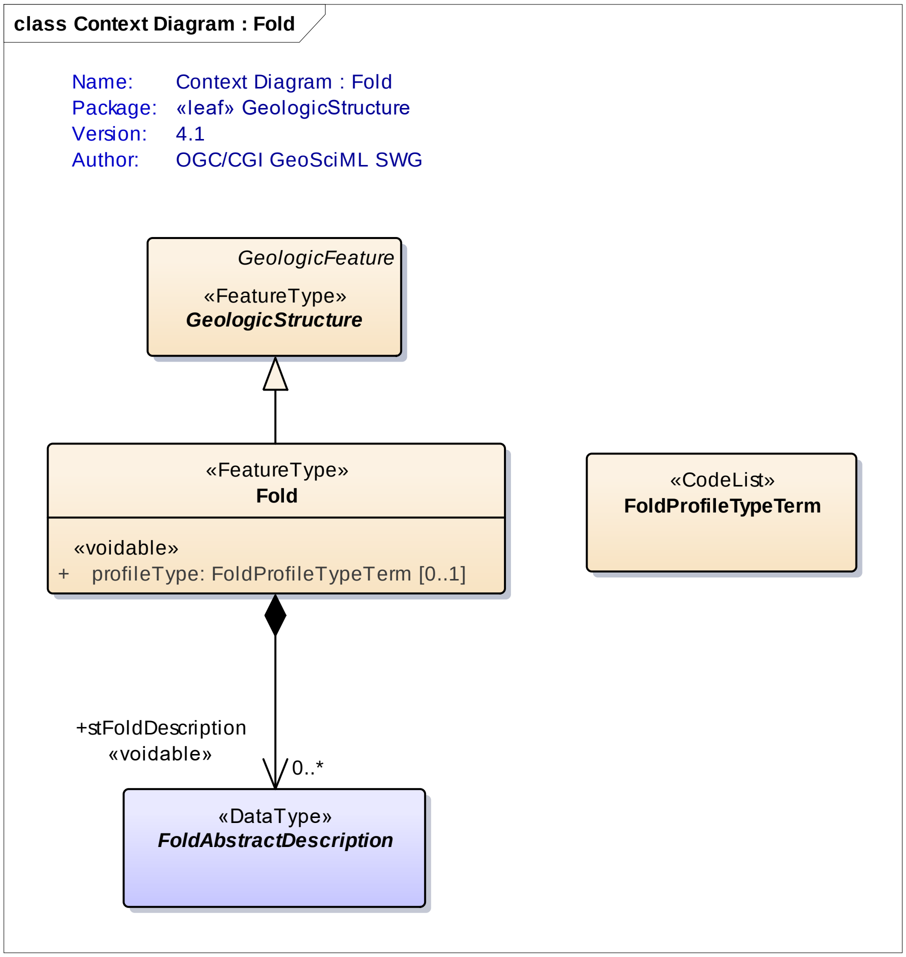


Figure 19 - Fold context diagram.

8.4.3.3.1 profileType

The property `profileType:FoldProfileTypeTerm` contains a term from a controlled vocabulary specifying the concave/convex geometry of fold relative to earth surface, and relationship to younging direction in folded strata if known. (e.g., antiform, synform, neutral, anticline, syncline, monocline, ptygmatic).

8.4.3.3.2 stFoldDescription (stub property)

The property `stFoldDescription:FoldAbstractDescription` provides a detailed fold description. This is a stub property in GeoSciML Basic since `FoldAbstractDescription` is an abstract class with subtypes defined in GeoSciML Extension.

8.4.3.4 Foliation

A foliation is a planar arrangement of textural or structural features in any type of rock. It includes any of a wide variety of penetrative planar geological structures that may be present in a rock. Examples include schistosity, mylonitic foliation, penetrative bedding structure (lamination), and cleavage. Following the proposed definition of gneiss by the NADM Science Language Technical Team [12], penetrative planar foliation defined by layers > 5 mm thick is considered `Layering`.

`Bedding` is a fabric representing the average orientation of paleodepositional surface and should be encoded through the foliationType property. It might apply to bedding that is layering or a foliation without layering (e.g. clast alignment in amalgamated beds).

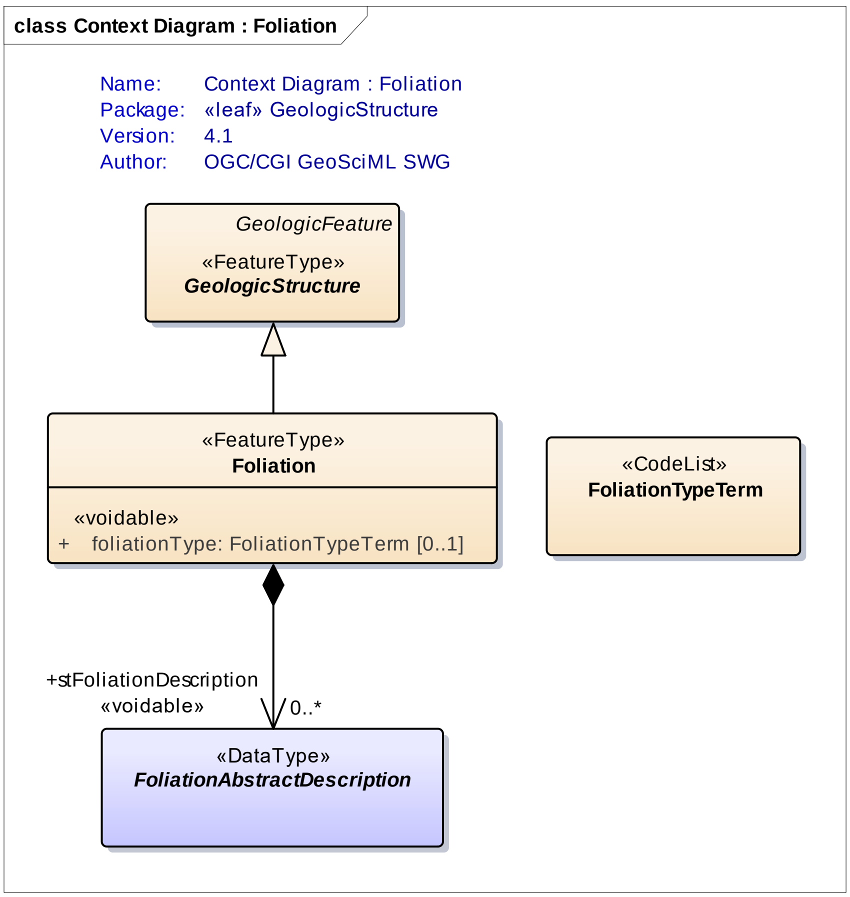


Figure 20 - Foliation context diagram

8.4.3.4.1 foliationType

The `foliationType:FoliationTypeTerm` property specifies the type of foliation from a controlled vocabulary. Examples include crenulation cleavage, slaty cleavage and schistosity.

8.4.3.4.2 stFoliationDescription (stub property)

The property `stFoliationDescription:FoliationAbstractDescription` provides a detailed foliation description. This is a stub property in GeoSciML Basic since `FoliationAbstractDescription` is an abstract class with subtypes defined in GeoSciML Extension.

8.4.3.5 ShearDisplacementStructure

A shear displacement structure includes all brittle to ductile style structures along which displacement has occurred, from a simple, single 'planar' brittle or ductile surface to a fault system comprised of tens of strands of both brittle and ductile nature. This structure may have some significant thickness (a deformation zone) and have an associated body of deformed rock that may be considered a deformation unit (which `geologicUnitType` is 'DeformationUnit') which can be associated to the ShearDisplacementStructure using `GeologicFeatureRelation` from the GeoSciML Extension package (8.5.1.2).

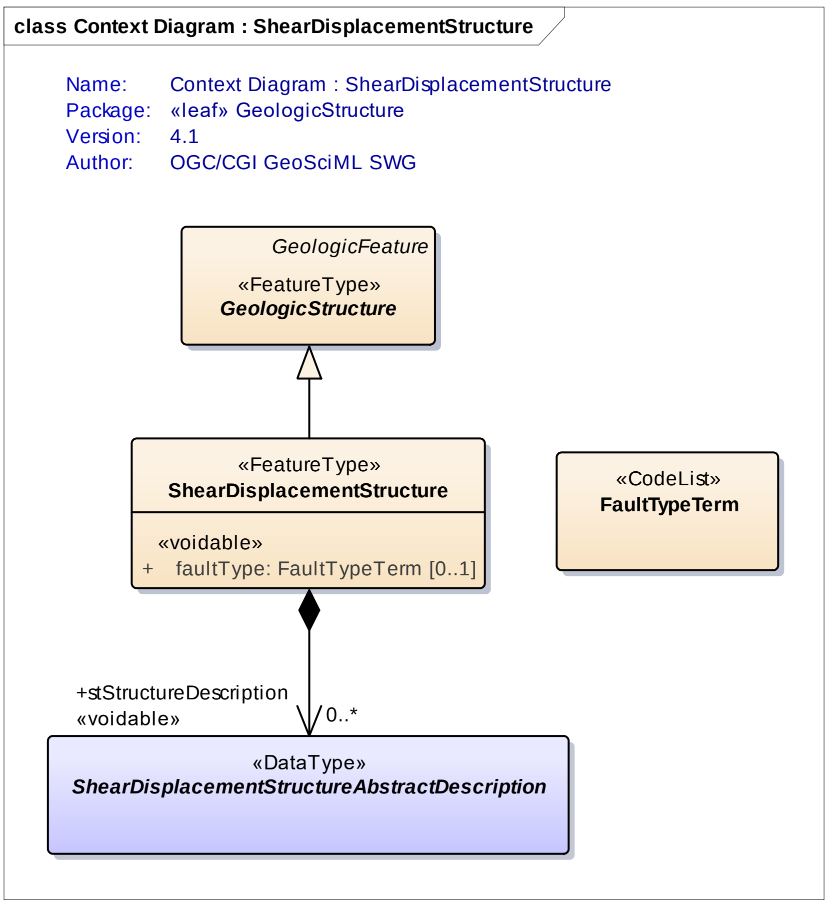


Figure 21 - ShearDisplacementStructure context diagram

8.4.3.5.1 *faultType*

The `faultType:FaultTypeTerm` property contains a term from a controlled vocabulary describing the type of shear displacement structure (e.g., thrust fault, normal fault or wrench fault).

8.4.3.5.2 *stStructureDescription*

The property `stStructureDescription:ShearDisplacementStructureAbstractDescription` provides a detailed geologic structure description. This is a stub property in GeoSciML Basic since `ShearDisplacementStructureAbstractDescription` is an abstract class with subtypes defined in GeoSciML Extension.

8.4.4 **Geomorphology**

The Geomorphology sub-package describes features that comprise the shape and nature of the Earth's land surface (i.e., landforms). These landforms may be created by natural or anthropogenic processes.

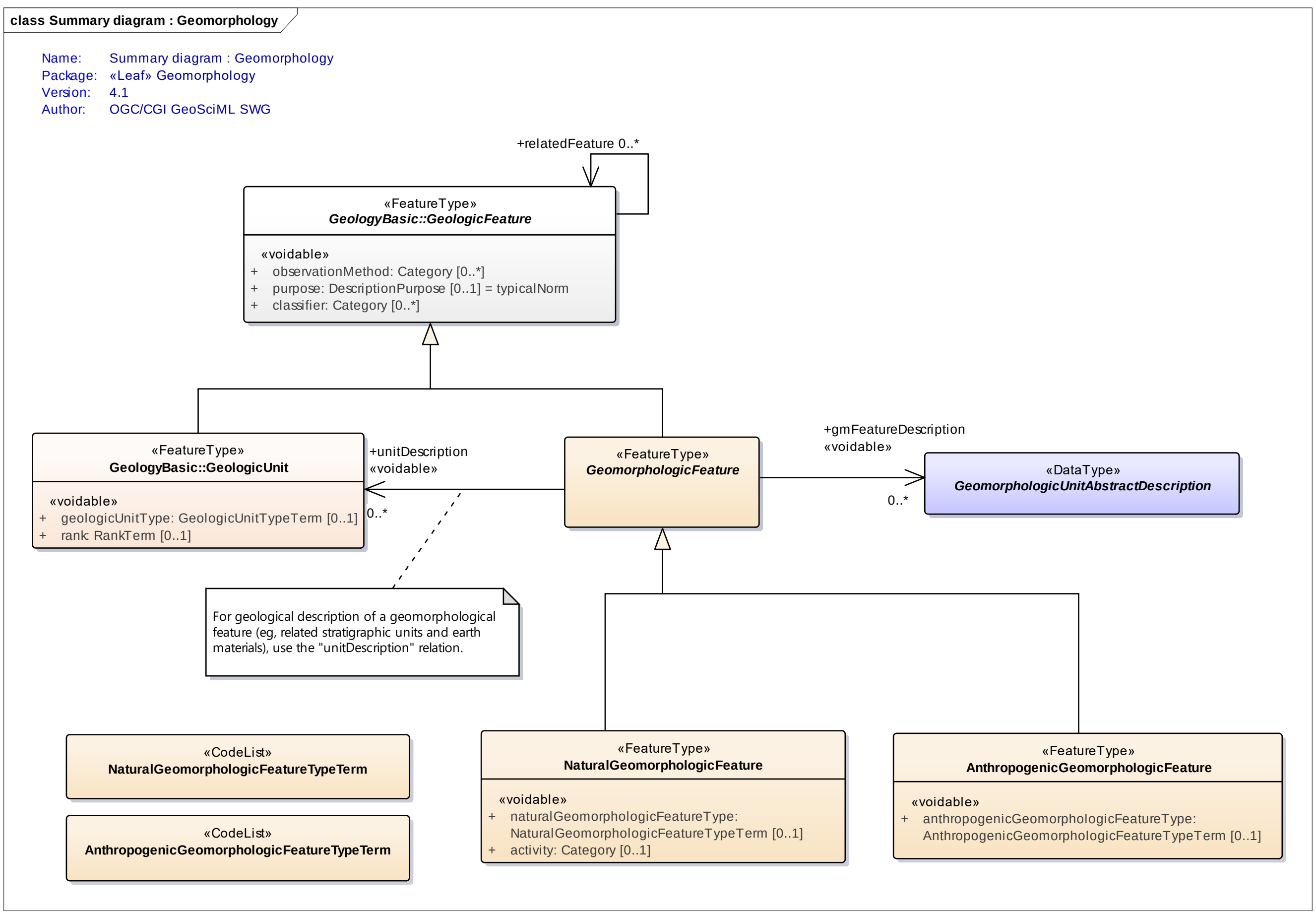


Figure 22 - Geomorphologic feature summary diagram

8.4.4.1 GeomorphologicFeature

A geomorphologic feature is a kind of `GeologicFeature` describing the shape and nature of the Earth's land surface. These landforms may be created by natural Earth processes (e.g., river channel, beach, moraine or mountain) or through human (anthropogenic) activity (e.g., dredged channel, reclaimed land, mine waste dumps). In GeoSciML, the geomorphologic feature is modelled as a feature related (through `unitDescription` property) to a `GeologicUnit` that composes the form.

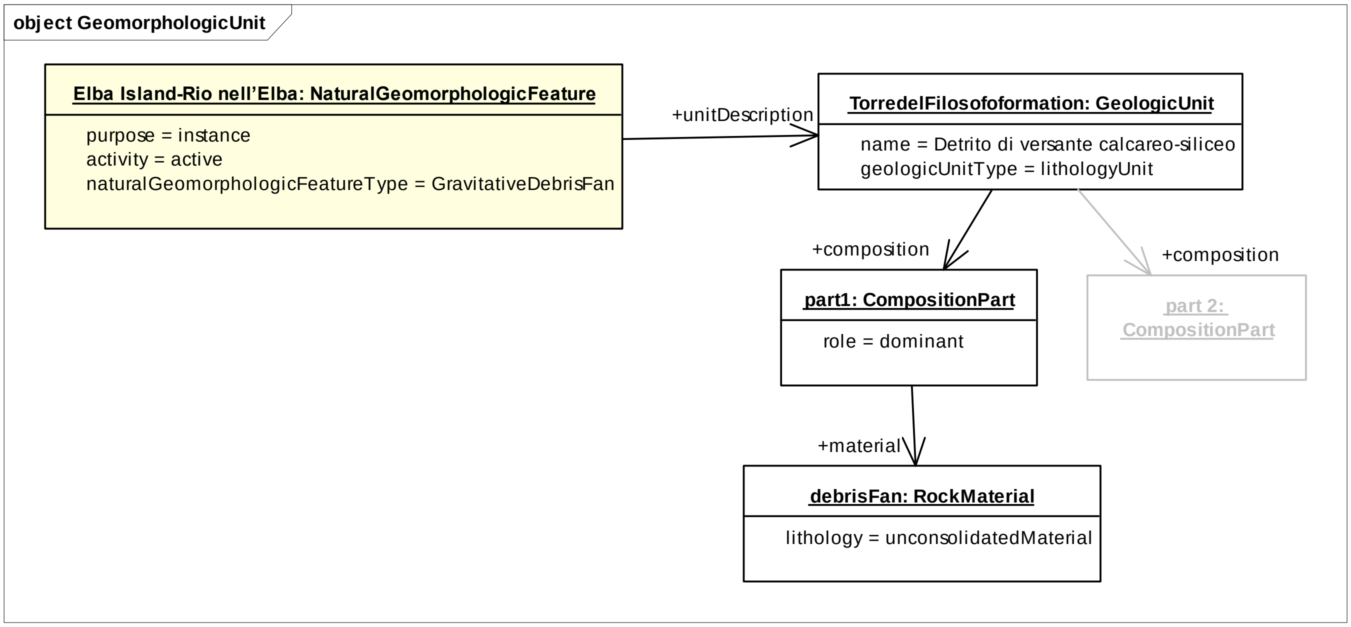


Figure 23 - Partial encoding of landform located in Elba Island as part of a geomorphological unit (encoded from a map from D'Orefice et al, 2009)

Figure 23 shows an example of GeoSciML encoding of a landform lava cone geomorphologic unit (from [2]) located in Elba Island showing how the geomorphologic feature is related to the geologic unit and materials that it is made of.

8.4.4.1.1 unitDescription

The `unitDescription` property is an association that links the geomorphologic feature to a geologic description (e.g., related stratigraphic units and earth materials).

8.4.4.1.2 gmFeatureDescription (stub property)

The property `gmFeatureDescription:GeomorphologicUnitAbstractDescription` provides a detailed morphologic description. This is a stub property in GeoSciML Basic since `GeomorphologicUnitAbstractDescription` is an abstract class with no concrete subtype in GeoSciML Basic.

8.4.4.2 NaturalGeomorphologicFeature

A natural geomorphologic feature is a geomorphologic feature (i.e., landform) that has been created by natural Earth processes. For example, river channel, beach ridge, caldera, canyon, moraine or mud flat.

8.4.4.2.1 naturalGeomorphologicFeatureType

The property `naturalGeomorphologicFeatureType: NaturalGeomorphologicFeatureTypeTerm` is a reference from a controlled vocabulary describing the type of geomorphologic feature.

8.4.4.2.2 activity

The `activity` property (`SWE::Category`) contains a category term from a controlled vocabulary describing the current activity status of the geomorphologic feature (e.g., currently active, dormant, inactive, reactivated, etc.).

8.4.4.3 AnthropogenicGeomorphologicFeature

An anthropogenic geomorphologic feature is a geomorphologic feature (i.e., landform) which has been created by human activity. For example, a dredged channel, midden, open pit or reclaimed land.

8.4.4.3.1 anthropogenicGeomorphologicFeatureType

The `anthropogenicGeomorphologicFeatureType: AnthropogenicGeomorphologicFeatureTypeTerm` is a reference from a controlled vocabulary describing the type of geomorphologic feature.

8.4.5 **Collection**

A GeoSciML collection is a convenience class to manage sets of features or type instances. A collection contains classes that facilitate the structuring of WFS response documents and other application uses.

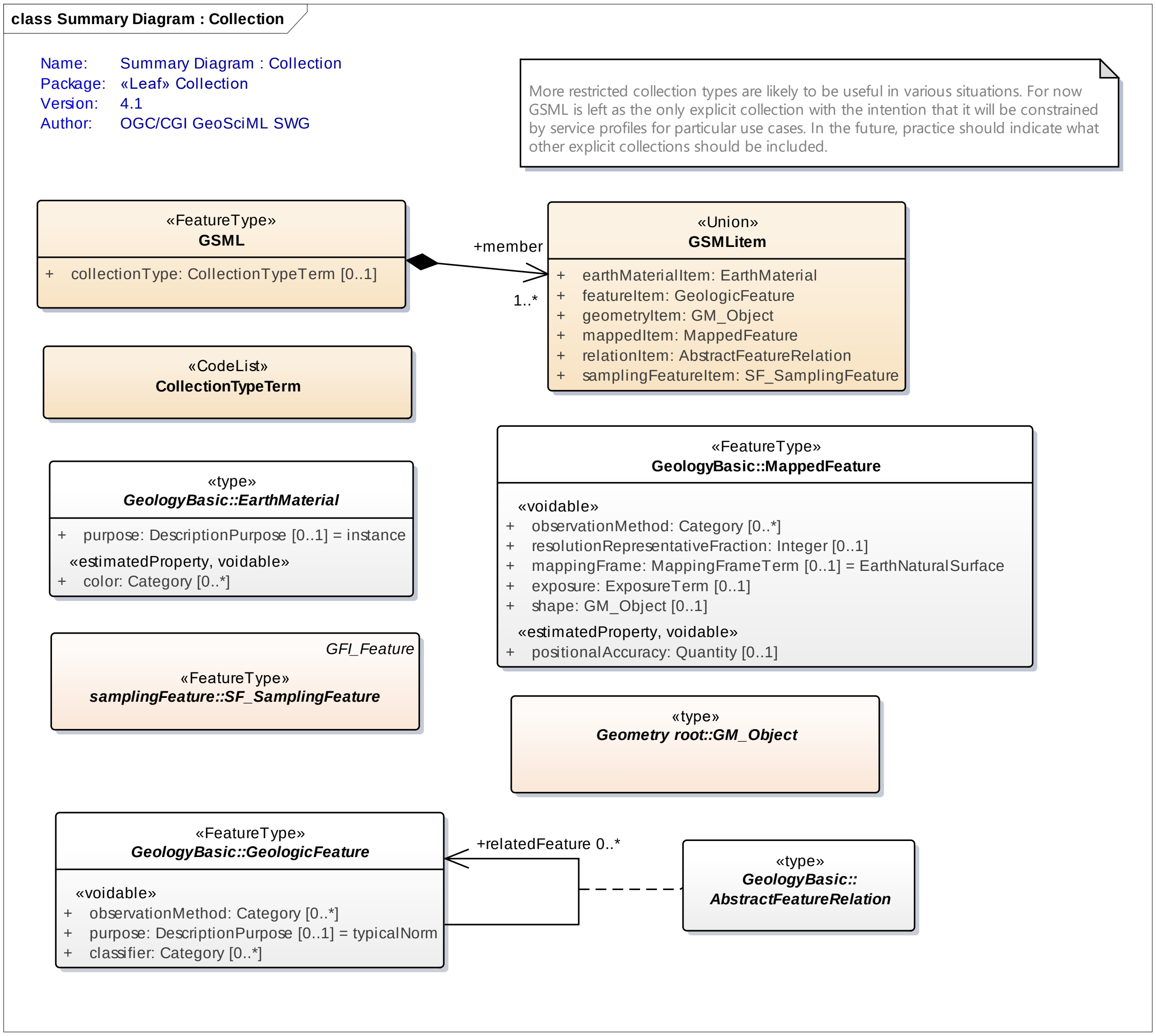


Figure 24 - GSML collection summary diagram.

8.4.5.1 GSML

`GSML` is a collection class grouping a set of features or types which are members of this collection. A `collectionType` property provides context or purpose.

8.4.5.1.1 member

The `member` property is an association that links a GSML instance to features and objects to be included as members of the collection. A collection can be made of heterogeneous items.

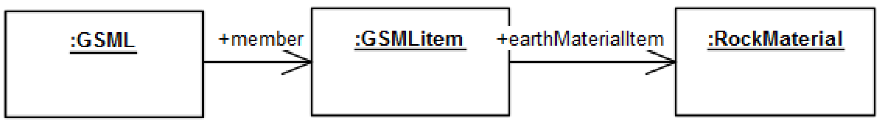
8.4.5.1.2 collectionType

The `collectionType:CollectionTypeTerm` property contains a term from a controlled vocabulary describing the type of collection, such as Geologic Map, Boreholes, 3D models.

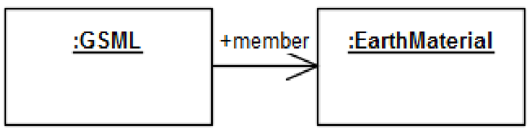
8.4.5.2 GSMLItem

`GSMLItem` (Figure 24) constrains the collection members to instances of `EarthMaterial`, `GeologicFeature`, `GM_Object`, `MappedFeature`, `AbstractFeatureRelation` and `OM::SF_SamplingFeature`. `GSMLItem` has the stereotype `<<Union>>` and according to ISO19103 (Clause 6.8.2), only one of the properties can be materialized at the time. It is important to note that the `<<Union>>` stereotype can be encoded in two distinct ways.

a) by materializing the GSMLItem (as prescribed by ISO 19136)



b) using GSMLItem as a validation constraint



This requirements class does not impose any encoding style for Union stereotype, although in the XML encoding requirements class (see 9.3) we chose the second option.

Table 3 - Types of GSMLItem members.

Property	Description
earthMaterialItem	The earthMaterialItem attribute is a placeholder for the EarthMaterial class that is included as a member of a GSML Collection.
featureItem	The featureItem attribute is a placeholder for the GeologicFeature class that is included as a member of a GSML Collection.
geometryItem	The geometryItem attribute is a placeholder for the AbstractGeometry class that is included as a member of a GSML Collection.
mappedItem	The mappedItem attribute is a placeholder for the MappedFeature class that is included as a member of a GSML Collection.

relationItem	The relationItem attribute is a placeholder for the GeologicRelation class that is included as a member of a GSML Collection.
samplingFeatureItem	The samplingFeatureItem attribute is a placeholder for the SamplingFeature class that is included as a member of a GSML Collection.

8.4.6 **GeoSciML data types**

GeoSciML Data is a package of data types that describes the planar or linear orientation of a geologic feature using conventions used in geology. They allow specifying direction by a numerical direction vector (e.g., dip/dip direction), or as a description (e.g., compass point (NE), or other text - "toward fold hinge", "below"). An additional `GSML_QuantityRange` class extends `SWE::QuantityRange` to allow upper and lower values in a numerical range to be delivered as two separate attributes. This is to facilitate query operations on upper and lower values by providing explicit names for these values (which are otherwise encoded as anonymous members of an array in SWE common).

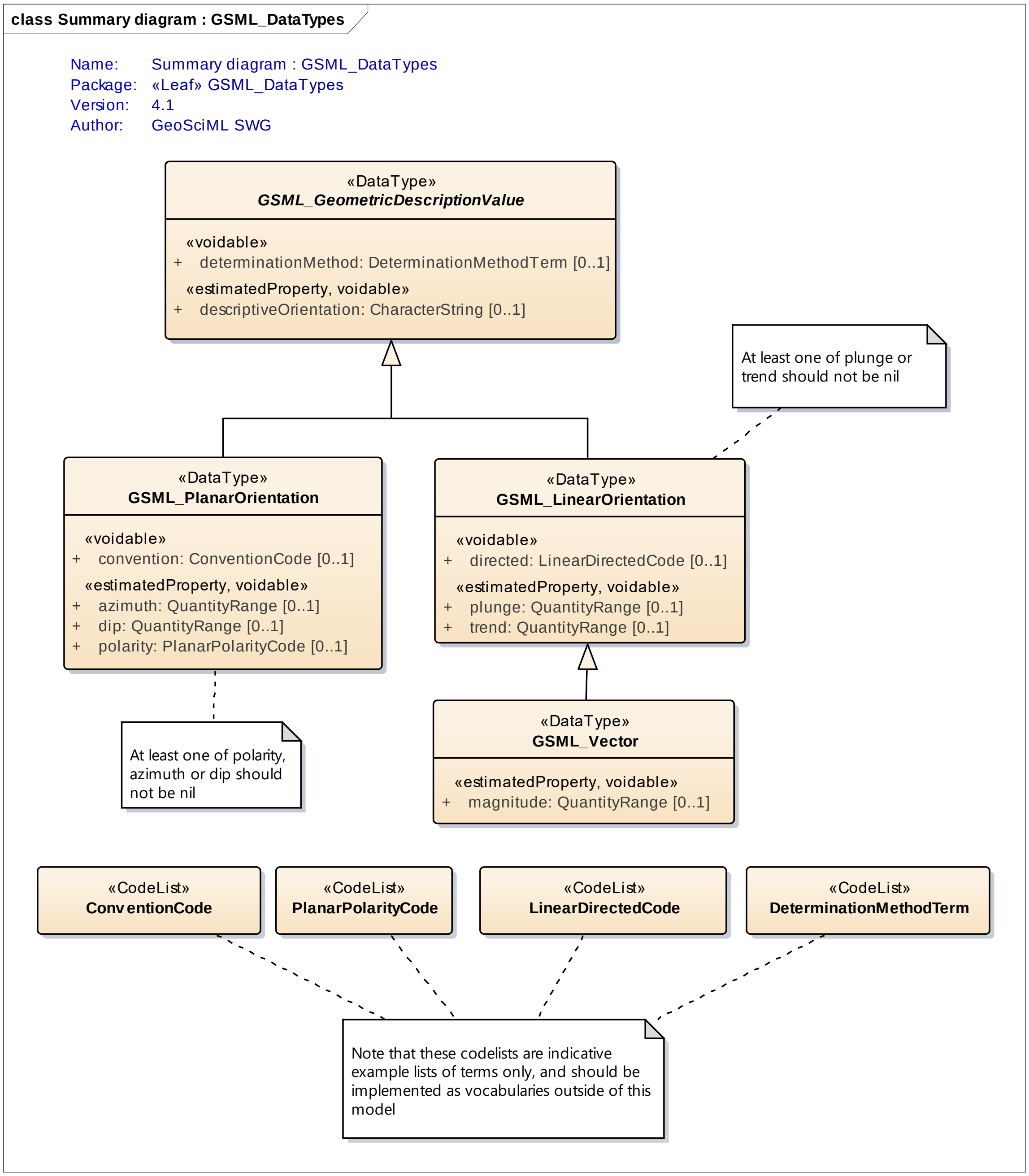


Figure 25 - Summary diagram of specialised GeoSciML data types

8.4.6.1 GSML_GeometricDescriptionValue

`GSML_GeometricDescriptionValue` is a special abstract data type for descriptions of planar or linear orientations of a geologic feature. Different subtypes allow specifying direction by direction vector (e.g. dip/dip direction), compass point (e.g. NE), or description (e.g. "toward fold hinge", "below').

8.4.6.1.1 determinationMethod

The `determinationMethod:DeterminationMethodTerm` property describes the way the orientation value was determined (e.g. measured, inferred from dip slope, etc.) using a reference to a controlled vocabulary.

8.4.6.1.2 descriptiveOrientation

The `descriptionOrientation:Primitive::CharacterString` contains a textual specification of orientation, possibly referencing some local geography (e.g. "toward fold hinge", "below").

8.4.6.2 GSML_PlanarOrientation

A planar orientation is composed of two values; the azimuth (a compass point) and a dip (the angle from the horizontal). Polarity of the plane indicates whether the planar orientation is associated with a directed feature that is overturned, upright, vertical, etc. There are several conventions to encode a planar orientation and this specification does not impose one but provides a `convention` property to report it. It must be noted that allowance for different conventions makes manipulation of the data more difficult. Therefore it is recommended that user communities adopt a single measurement convention.

/req/gsml4-basic/plane-pol-dip-az-not-null	At least one of polarity, azimuth or dip SHALL not be null.

To have any meaningful value, the planar orientation shall have at least a value for polarity, azimuth or dip.

8.4.6.2.1 convention

The property `convention:ConventionCode` contains the convention used for the measurement from a controlled vocabulary.

8.4.6.2.2 azimuth

The `azimuth` (`SWE::QuantityRange`) property (compass point, bearing etc.) contains the value of the orientation. The convention property (8.4.6.2.1) reports how azimuth is interpreted (if it is relative to a quadrant).

8.4.6.2.3 dip

The `dip` (`SWE::QuantityRange`) reports the angle that the structural surface (e.g. bedding, fault plane) makes with the horizontal measured perpendicular to the strike of the structure and in the vertical plane as a numeric value or term.

8.4.6.2.4 polarity

The `polarity:PolarityCode` indicates whether the planar orientation is associated with a directed feature that is overturned, upright, vertical etc., using a controlled vocabulary.

8.4.6.3 GSML_LinearOrientation

A linear orientation is composed of a trend (the compass orientation of the line) and a plunge (the angle from the horizontal). This vector may be oriented (pointing in a specific direction) or not.

/req/gsml4-basic/linear-trend-plunge-not-null	At least one of plunge or trend SHALL NOT be null.

To have any meaningful value, an instance of `GSML_LinearOrientation` shall at least have a trend or a plunge value.

8.4.6.3.1 directed

The `directed:LinearDirectedCode` property indicates if the orientation represents a linear feature that is directed, e.g. clast imbrication, mylonitic lineation with sense of shear, slickenlines with displacement direction, rather than undirected (like a fold hinge line or intersection lineations). A code list will indicate which is the directed end of the linear orientation. The value of the property comes from a controlled vocabulary.

8.4.6.3.2 plunge

The property `plunge` (`SWE::QuantityRange`) reports the magnitude of the plunge as an angle from horizontal.

8.4.6.3.3 trend

The property `trend` (`SWE::QuantityRange`) reports the azimuth (compass bearing) value of the linear orientation.

8.4.6.4 GSML_Vector

A `GSML_Vector` is a data type representing a linear orientation with a magnitude (a quantity assigned to this vector). If the magnitude is unknown, a `GSML_LinearOrientation` (8.4.6.3) shall be used.

8.4.6.4.1 magnitude

The magnitude `property` (`SWE::QuantityRange`) reports the magnitude of the vector.

8.4.6.5 GSML_QuantityRange

`GSML_QuantityRange` is a specialization of SWE Common `QuantiytyRange` (OGC 08-094r1, Clause 7.2.13) where lower and upper values are made explicit. `SWE::QuantityRange` uses an array of values (RealPair, see Clause 7.2.1) where the lowest value is the first element and the highest the second. This convenience data type has been created as an alternative encoding for implementations that do no support encoding of arrays in a single field (e.g. DBF) or reference to elements in string encoded arrays[3] (eg. Filter Encoding Specification 2.0 – OGC 09-029r2).

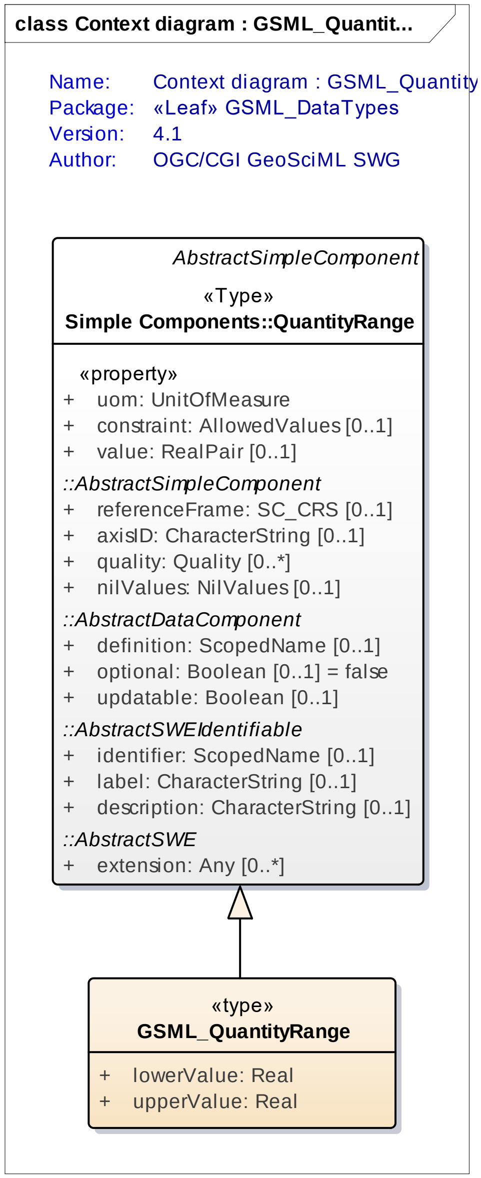


Figure 26 - Context diagram for QuantityRange making lower and upper values explicit

The `lowerValue` shall be less than or equal to the `upperValue`.

[3] `SWE RealPair` is encoded as space delimited lists (`<swe:value>10 300</swe:value>` in XML) , which demands that clients parse the string to extract each token. To build a WFS/FES query that tests the first element, it requires parsing the string either using `string-before(swe:value,' ')` or `tokenize(swe:value,' ')`. This is cumbersome at best, or not even supported by the server at worst. 09-026r2 Clause 7.4.4 describes the minimal XPath supports and string parsing is not present.

/req/gsml4-basic/quantity-range-order	The QuantityRange lowerValue SHALL be less than or equal to the upperValue.

The values reported in `lowerValue` and `upperValue` shall be the same as the pair of values in inherited values property.

/req/gsml4-basic/quantity-range-repeat	The QuantityRange's value[0] SHALL provide the same value as lowerValue and value[1] SHALL provide the same value as upperValue.

8.4.6.5.1 lowerValue

The property `lowerValue:Real` contains the lower bound of the range. It shall be a copy of inherited `SWE::QuantityRange::value[0]`.

8.4.6.5.2 upperValue

The property `upperValue:Real` contains the upper bound of the range. It shall be a copy of inherited `SWE::QuantityRange::value[1]`.

Example:

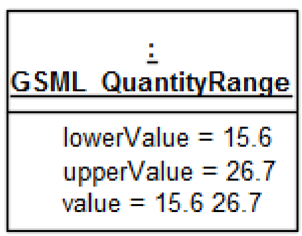


Figure 27 - Encoding of a quantity range of [15.6,26.7]. Note that the value is encoded in both lowerValue, upperValue and in value as an array.

8.4.7 **GeoSciML Basic vocabularies**

Geology is a descriptive science and uses vocabularies extensively. Table 4 lists the vocabularies used in GeoSciML Basic. Each of those vocabularies shall be implemented using externally managed vocabularies as specified in clause 8.2.7

Table 4 - Vocabularies used in GeoSciML Basic.

Vocabulary	**Description**
CompositionPartRoleTerm	This class is a blank placeholder for a vocabulary of terms to describe the role that a compositional part plays in a geologic unit.
DescriptionPurpose	Codes used for the specification of the intended purpose/level of abstraction for a given feature or object instance, i.e. the reason for the existence of the GeologicFeature. Values shall be either: instance, typicalNorm or

	definingNorm.
ExposureTerm	This class is a blank placeholder for a vocabulary of terms describing the nature of the expression of the mapped feature at the earth's surface (e.g., exposed, concealed).
GeologicUnitHierarchyRoleTerm	Role of the unit in the hierarchy.
GeologicUnitTypeTerm	This class is an indicative placeholder only for a vocabulary of terms describing the type of geologic unit. Users are encouraged to use the vocabulary of unit types provided by the CGI vocabularies working group. Example of values: GeologicUnit, AllostratigraphicUnit, AlterationUnit, ArtificialGround, BiostratigraphicUnit, ChronostratigraphicUnit, DeformationUnit, ExcavationUnit, GeophysicalUnit, LithodemicUnit, LithogeneticUnit, LithologicUnit, LithostratigraphicUnit, LithotectonicUnit, MagnetostratigraphicUnit, MassMovementUnit, Pedoderm, PedostratigraphicUnit, PolarityChronostratigraphicUnit.
GeologicUnitPartRoleTerm	This class is a blank placeholder for a vocabulary of terms describing the nature of the parts of a geologic unit, e.g. facies, stratigraphic, interbeds, geographic, eastern facies.
LithologyTerm	Refers to a vocabulary of terms describing the lithology of the compound earth material (e.g., granite, sandstone, schist)
MappingFrameTerm	A mapping surface, a section, a Borehole.
RankTerm	This class is a blank placeholder for a vocabulary of terms describing the rank of a geologic unit (e.g., Group, Formation, Member, etc.).
CollectionTypeTerm	Types of collections of geological and geophysical objects.
EventProcessTerm	Refers to a vocabulary of terms specifying the process or processes that occurred during an event. Examples include deposition, extrusion, intrusion, cooling.
GeochronologicEraTerm	Term from a Geochronological vocabulary
ContactTypeTerm	Refers to a vocabulary of terms describing types of geological contacts
FaultTypeTerm	A vocabulary of terms describing the type of shear displacement structure (e.g., thrust fault, normal fault, wrench fault)
FoldProfileTypeTerm	Refers to a vocabulary of terms specifying concave/convex geometry of fold relative to earth surface, and relationship to younging direction in folded strata if known. antiform, synform, neutral, anticline, syncline, monocline, ptygmatic

FoliationTypeTerm	Refers to a vocabulary of terms defining the type of foliation (e.g., crenulation cleavage, gneissic layering, slaty cleavage, schistosity, etc.)
AnthropogenicGeomorphologicFeatureTypeTerm	Refers to a vocabulary of terms describing the type of anthropogenic geomorphologic feature
NaturalGeomorphologicFeatureTypeTerm	Refers to a vocabulary of terms describing the type of natural geomorphologic feature
ConventionCode	Suggested values: "dip dip direction", "strike dip right hand rule" (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.) This list is an indicative list only of terms used to describe the convention used for the orientation measurement. Users are encouraged to use a vocabulary of terms managed by the CGI vocabularies working group outside of this model.
DeterminationMethodTerm	This class is an empty placeholder for a vocabulary of terms describing the method used to determine the measured orientation. Users are encouraged to use a vocabulary of terms managed by the CGI vocabularies working group outside of this model.
LinearDirectedCode	Examples • "directed" (indicates that the 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) This list is an indicative example list only of terms used to describe the values to use for terms related to directedness of linear orientations. Users are encouraged to use a vocabulary of terms managed by the CGI vocabularies working group outside of this model.
PlanarPolarityCode	This list is an indicative list only of terms used to describe the values to use for expressing overturned or upright facing of planar orientation measurements. Users are encouraged to use a vocabulary of terms managed by the CGI vocabularies working group outside of this model. e.g., "upright", "overturned", "vertical"

8.4.8 Instance examples

The following figure shows a partial encoding of an existing map from Drewes [3]. This example has been chosen because it was selected for a similar exercise for the North American Data Model (http://ngmdb.usgs.gov/www-nadm/dmdt/). Figure 28 shows a small section of a map showing unit Ttv (Dacitic vent breccia) from a quadrangle in Arizona, USA. The original legend description is shown in Figure 29.

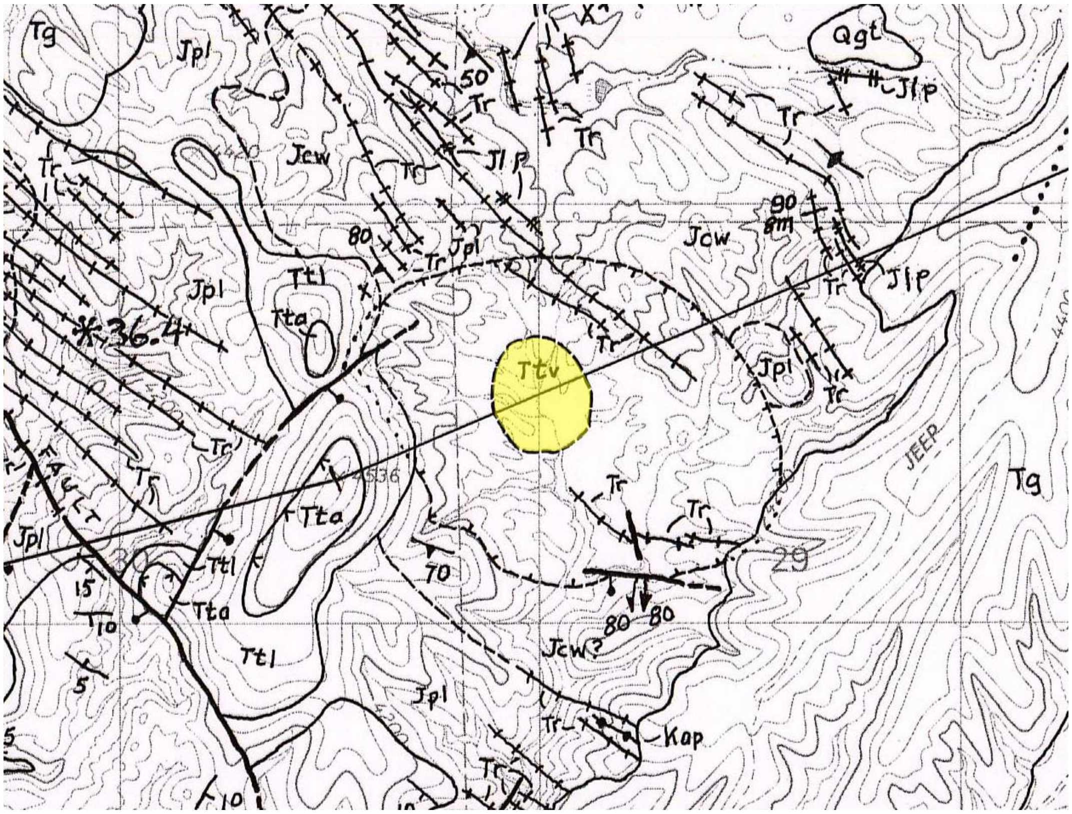


Figure 28 - Excerpt from Drewes map [3] with a Dacitic vent breccia unit highlighted (Ttv)

Ttv **Dacitic vent breccia**—Light-medium-gray, finely porphyritic dacitic rock containing inclusions of Jurassic or Proterozoic granite and Jurassic rhyolite (welded tuff?) as much as 20 m in diameter. The subcircular outcrop mass of breccia probably is a volcanic vent or throat. A halo of strongly sausseritized rock 0.3–0.5 km wide surrounds this vent. The dacitic matrix consists of phenocrysts (25–35 percent, as much as 2 mm in length) set in a cryptocrystalline granular groundmass. Phenocrysts include albitized(?) plagioclase (12–18 percent), chloritized biotite (2–5 percent), uralitized amphibole (2–10 percent), magnetite (trace to 2 percent), and apatite (trace amount). Quartz is present as a secondary mineral, filling vugs

Figure 29 - Original description from Drewes map [3] legend. This legend item is represented as a GeologicFeature (specifically, a GeologicUnit)

The map also has a cross section through the same Ttv unit (

Figure 30) showing an example of a non-map mapping frame.

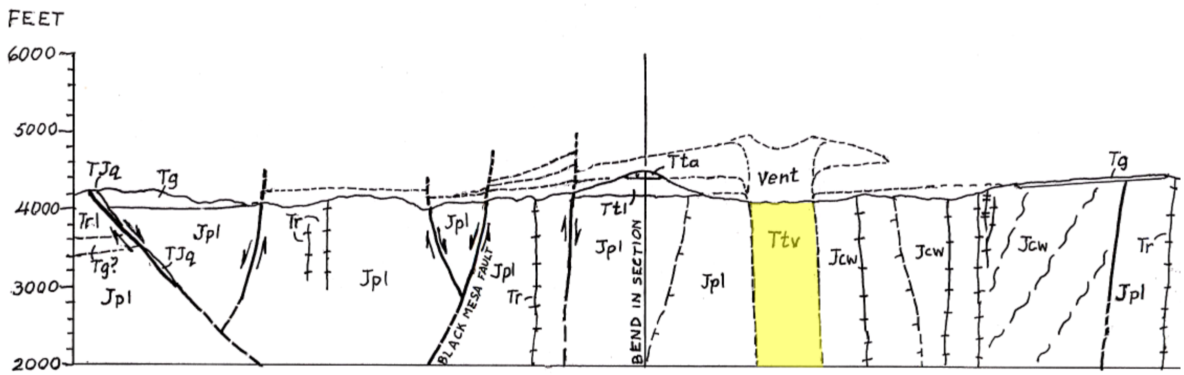


Figure 30 - The same Dacitic vent breccia unit, shown in a cross section (a different MappingFrame)

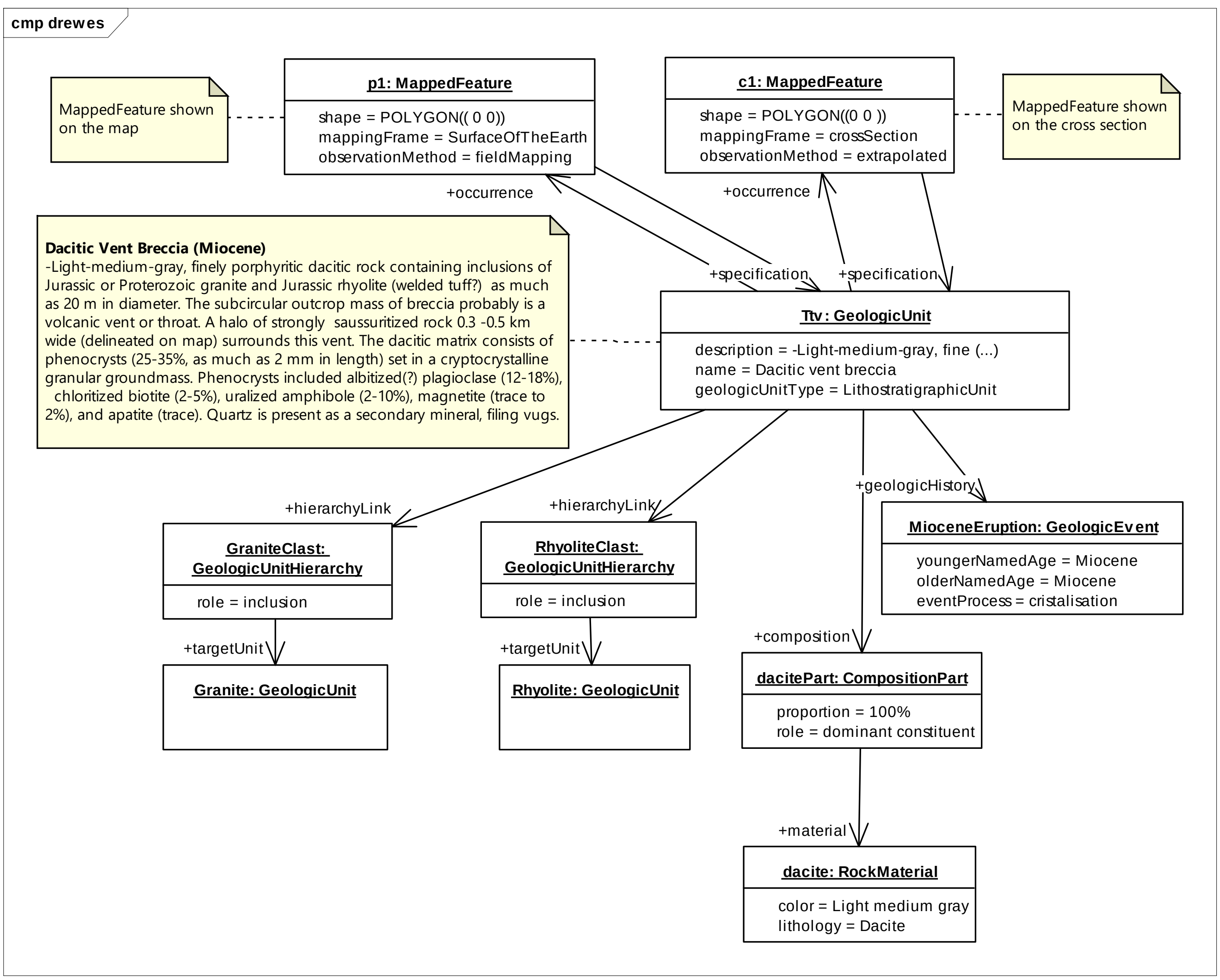


Figure 31 - Partial encoding of the Dacitic vent breccia unit from Drewes' map [3] partitioned into GeoSciML instances.

8.5 GeoSciML Extension Requirements Class (Normative)

Requirements Class	
/req/gsml4-extension	
Target type	Encoding
Dependency	/req/gsml4-basic
Dependency	/req/gsml4-geologictime
Requirement	**/req/gsml4-extension/geologicfeature-history** A `GeologicFeatureRelation` SHALL not be used to associate a `GeologicFeature` to a `GeologicEvent` if `GeologicFeature::geologicHistory` can provide the same information.
Requirement	**/req/gsml4-extension/contact-chronoboundary** `correlatesWith` association to a `GeochronologicBondary` SHALL be allowed only when `contactType` = ChronostratigraphicBoundary.
Requirement	**/req/gsml4-extension/slipComponents-slip** `SlipComponents` SHALL have at least one of heave, horizontalSlip or throw as a non-null value.

The extension package provides classes to further the descriptions of basic classes by adding more properties and supplemental relations. It extends abstract description stubs declared in basic package and introduces new `GeologicStructure` features.

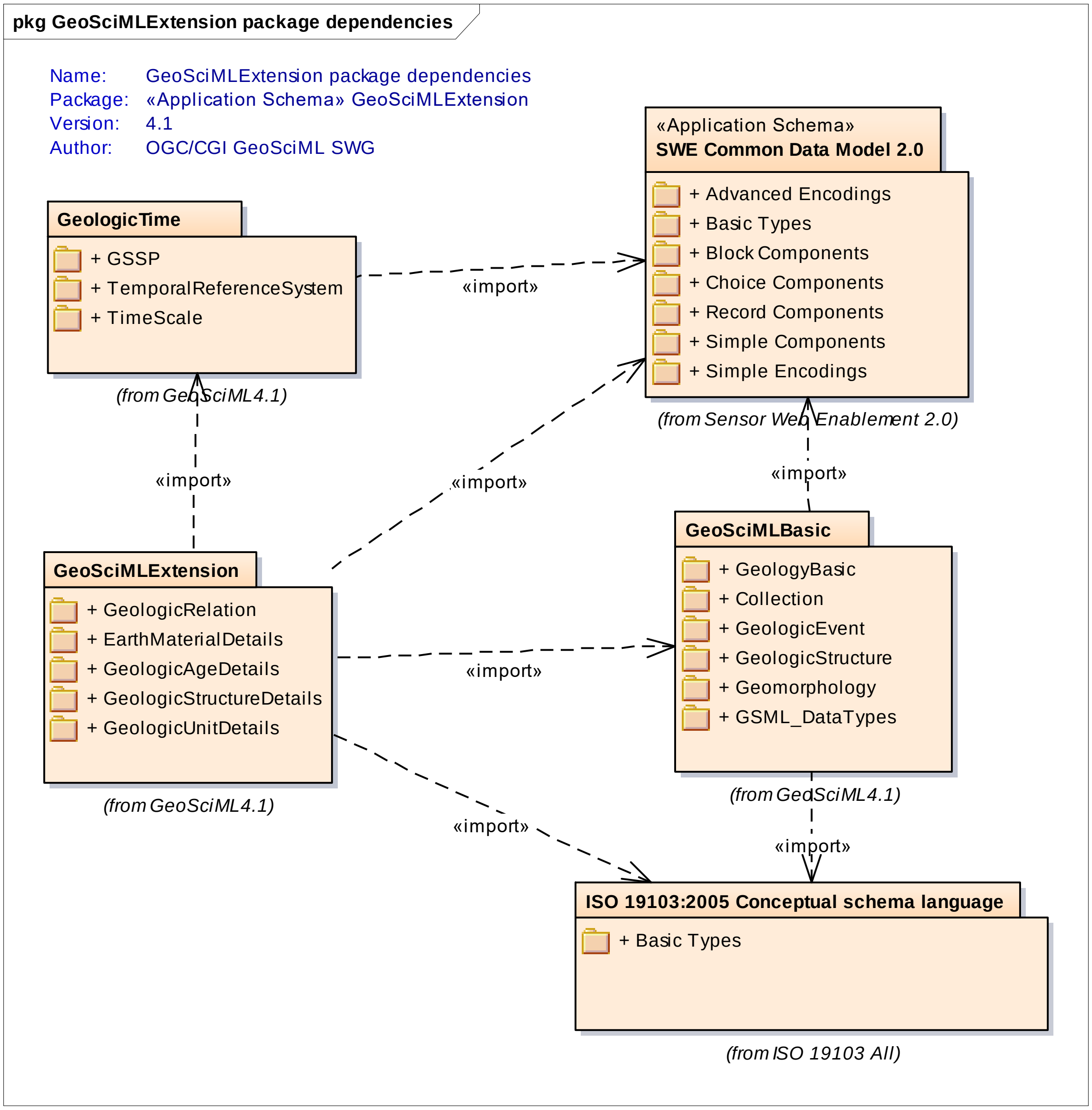


Figure 32 - GeoSciML extension package dependencies.

8.5.1 GeologicRelation

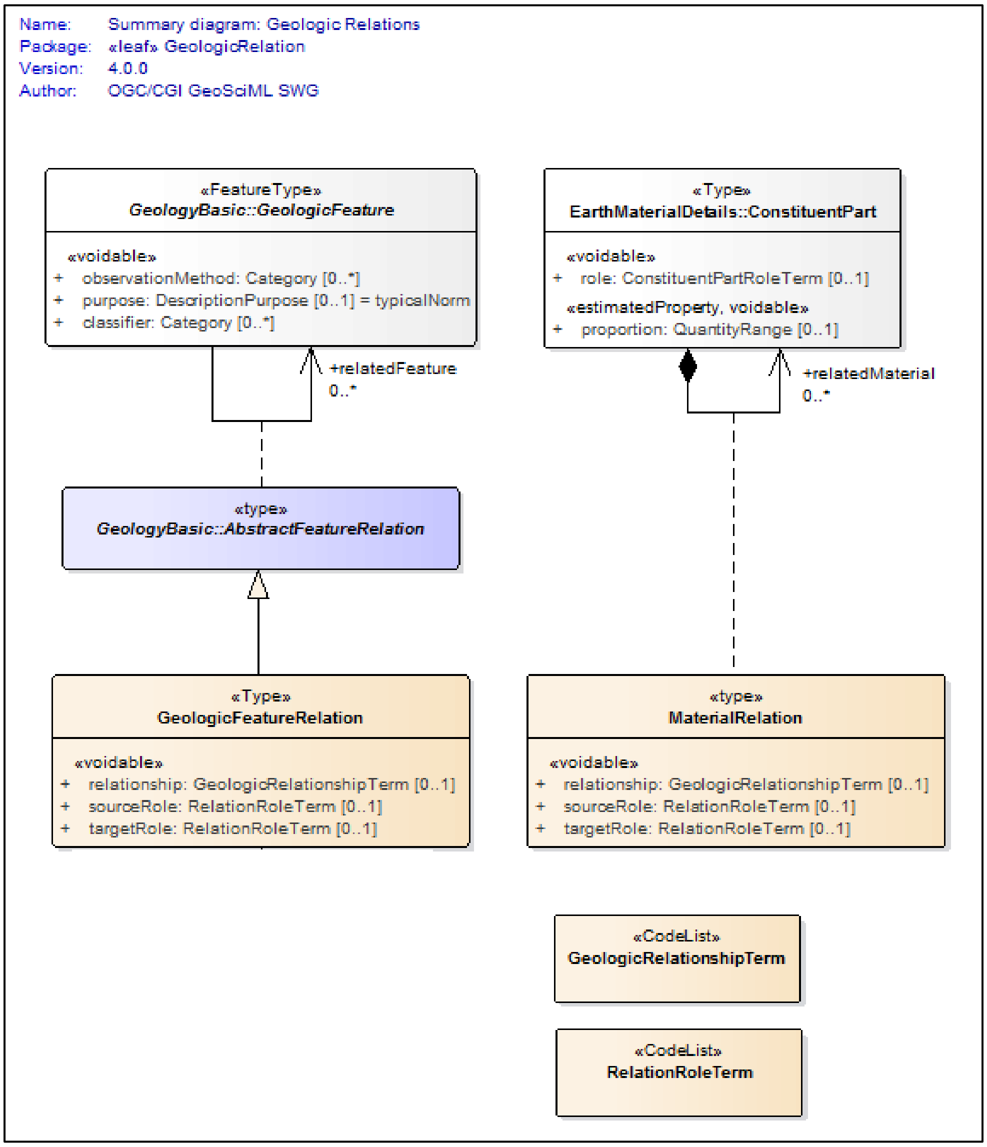


Figure 33 - Summary diagram of GeologicFeatureRelation as a concrete subtype of AbstractFeatureRelation stub class

8.5.1.1 GeologicHistory

GeoSciML uses the generic `relatedFeature:GeologicFeatureRelation` to associate `GeologicFeature` with other `GeologicFeatures`, which includes `GeologicEvents`. However, this functionality is only available from the Extension package because it adds extra complexity that Basic hopes to avoid.

To allow geologic age description in GeoSciML Basic without `GeologicFeatureRelation`, `GeologicFeature` has an explicit `geologicHistory` property to associate `GeologicFeature` with a `GeologicEvent`. The consequence for someone using GeoSciML Extension is the presence of two different ways to link a `GeologicFeature` and `GeologicEvent`:

1. A direct association through `geologicHistory`
2. A generic `GeologicFeatureRelation`.

To prevent confusion and promote consistency, especially in query scenarios, association between `GeologicFeature` and `GeologicEvent`, for the purpose of describing geologic history, and therefore geologic age, shall use the `geologicHistory` property. A `GeologicFeatureRelation` can be used in any other circumstances.

/req/gsml4-extension/geologicfeature-history	A `GeologicFeatureRelation` SHALL not be used between a `GeologicFeature` and `GeologicEvent` if `GeologicFeature::geologicHistory` can provide the same information.

8.5.1.2 GeologicFeatureRelation

The `GeologicFeatureRelation` class defines the general structure used to define relationships between any GeoSciML feature types. Relationships are always binary and directional. There is always a single source and a single target. The relationship is always defined from the perspective of the Source and is generally an active verb.

Example: a Source may point to an intrusive igneous rock unit. In this case, the Target would point to the appropriate host rock body and the relationship attribute would be 'intrudes'. Other appropriate relationship attributes might include: overlies, offsets, crosscuts, folds, etc.

Many other types of relationships can also be accommodated via GeologicRelation, for example, topological relations could be described where they are geologically significant.

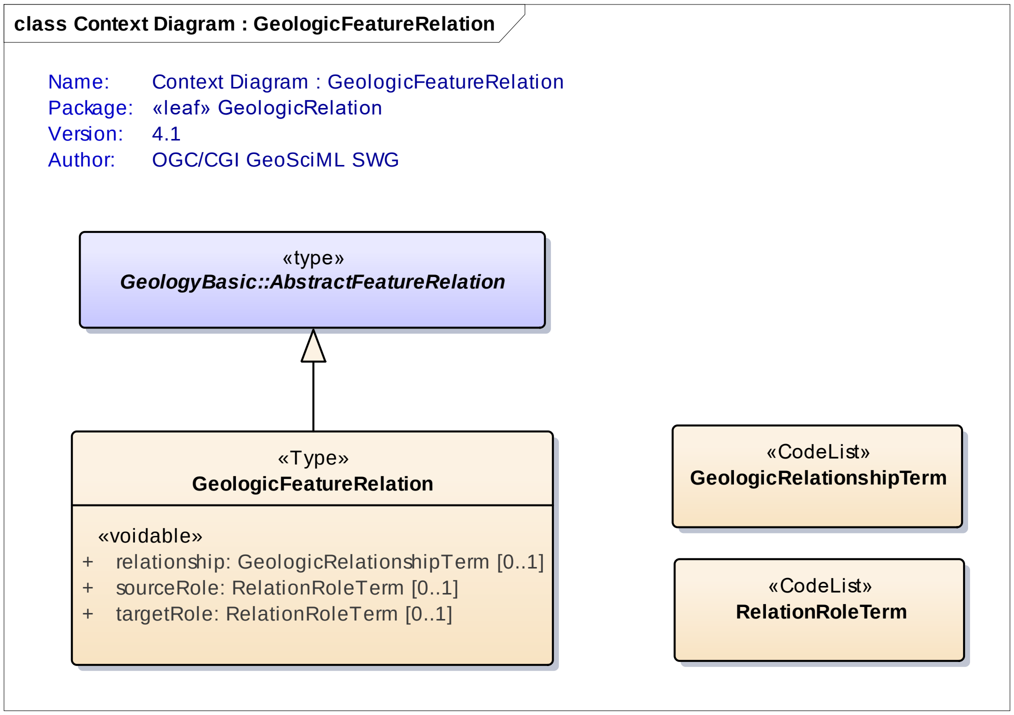


Figure 34 - Generic geologic feature relation

8.5.1.2.1 relationship

The `relationship:GeologicRelationshipTerm` property contains a term from a controlled vocabulary to describe the geologic relationship (e.g., stratigraphic relation, structural relation, intrusive relation).

8.5.1.2.2 sourceRole

The property `sourceRole:RelationRoleProperty` contains a term from a controlled vocabulary describing the role played by the source geologic feature or object (e.g., overlying unit, underlying unit).

8.5.1.2.3 targetRole

The property `targetRole:RelationRoleTerm` contains a term from a controlled vocabulary describing the role played by the target geologic feature or object. (e.g., overlying unit, underlying unit)

8.5.1.3 MaterialRelation

The `MaterialRelation` class describes the relationships between constituent parts in an `EarthMaterial` (e.g. A mineral overgrowth on a phenocryst within a granite).

Example: Consider an overgrowth of albite on plagioclase in a granite. The Source would originate with the albite constituentPart description. In this case, the Target would point to the plagioclase `constituentPart` description and the relationship attribute would be 'overgrowth' and the `sourceRole` is 'overgrows'. Other appropriate role attributes might include: crosscuts, replaces, etc. for crosscutting and replacement relationships. Inverse relationships must be explicitly recorded.

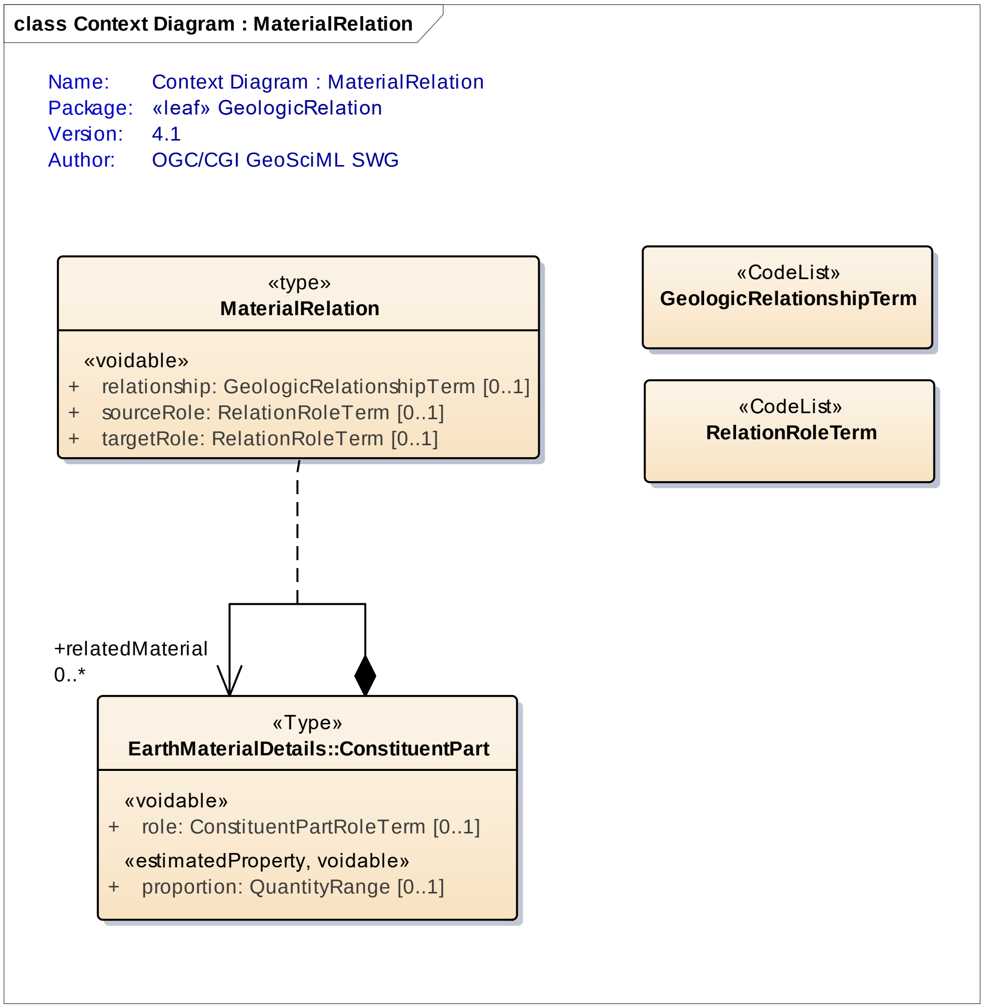


Figure 35 - Material relation context diagram.

8.5.1.3.1 relationship

The property `relationship:GeologicRelationshipTerm` contains a term from a controlled vocabulary to describe the geologic relationship (e.g., sedimentary relation, igneous relation).

8.5.1.3.2 sourceRole

The property `sourceRole:RelationRoleTerm` contains a term that describes the role played by the source earth material part (e.g., matrix, clast, overgrowth).

8.5.1.3.3 targetRole

The property `targetRole:RelationRoleTerm` contains a term describing the role played by the target earth material part (e.g., matrix, clast, overgrowth).

8.5.2 EarthMaterialDetails

EarthMaterialDescription abstract class is materialised into a series of concrete classes to address various aspects of EarthMaterial descriptions:

- CompositionDescription
- FabricDescription
- RockMaterialDescription
- AlterationDescription
- PhysicalDescription
- MetamorphicDescription
- CompoundMaterialDescription

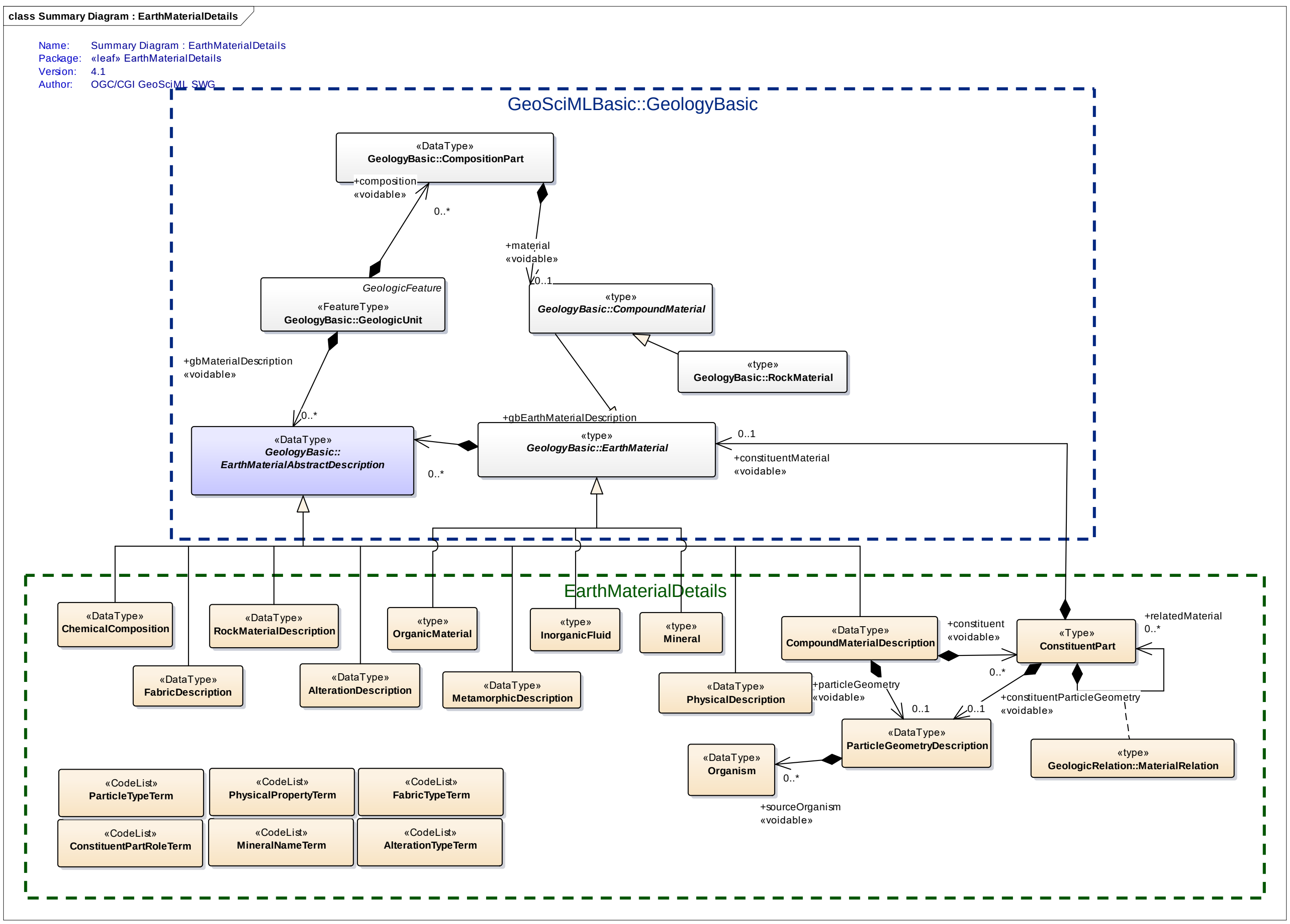


Figure 36 - Overview of earth material description.

8.5.2.1 AlterationDescription

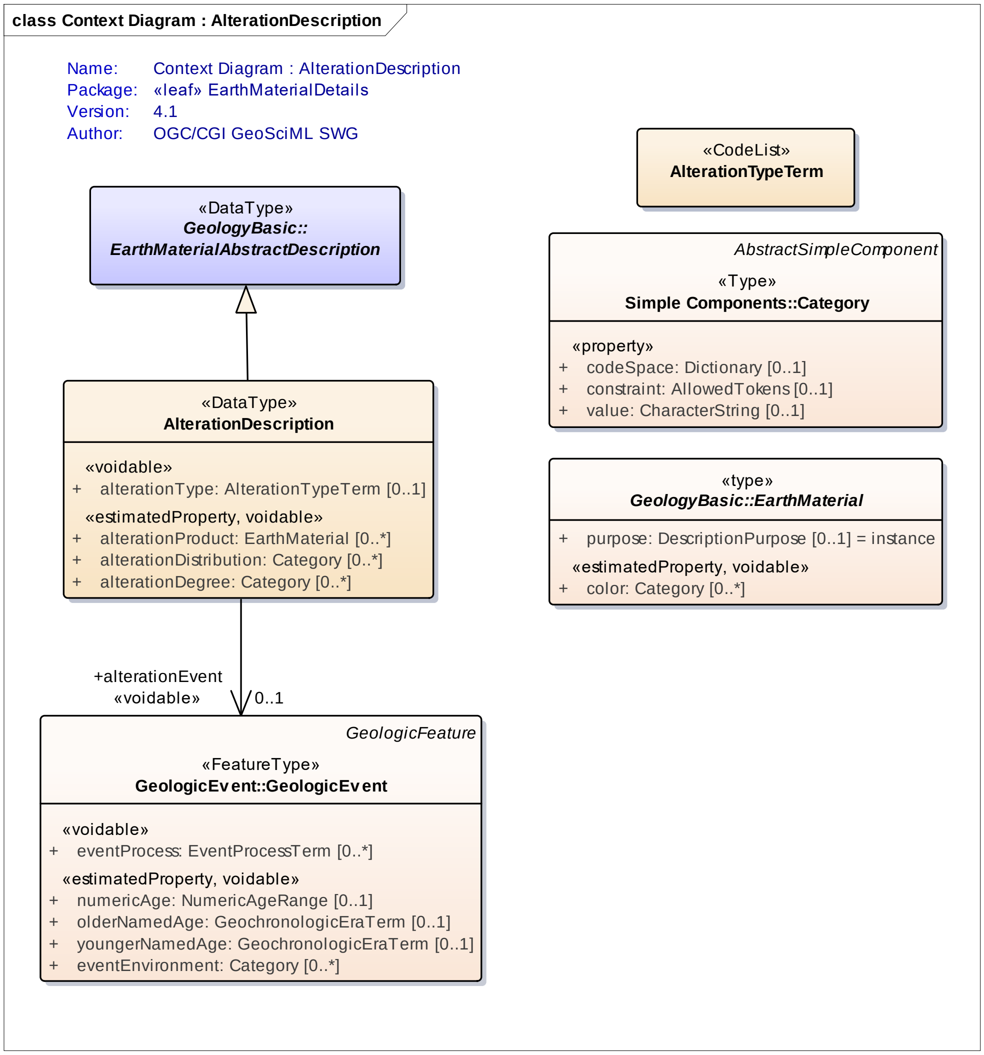


Figure 37 - Alteration description context diagram.

AlterationDescription describes aspects of a geologic unit or earth material that are the result of bulk chemical, mineralogical or physical changes related to change in the physical or chemical environment. It includes weathering, supergene alteration, hydrothermal alteration and metasomatic effects not considered metamorphic. For example, a soil profile description would have to be constructed as a GeologicUnit (geologicUnitType = PedologicUnit) with unit parts representing the various horizons in the profile. Thickness of a weathering profile can be delivered as unitThickness of a GeologicUnit of geologicUnitType equal to "AlterationUnit" (Figure 38).

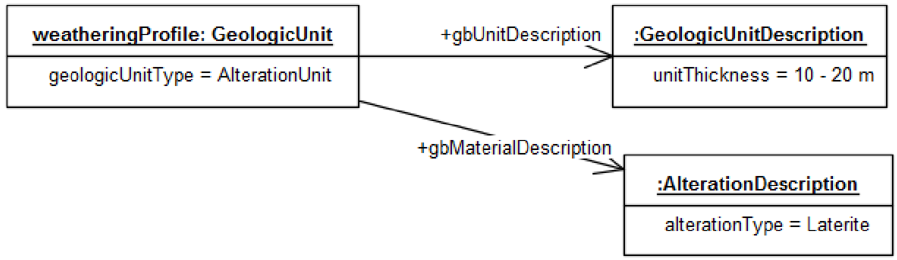


Figure 38 - Example of a weathering profile.

An example encoding of an altered geologic unit from Drewes [3] is shown in Figure 39.

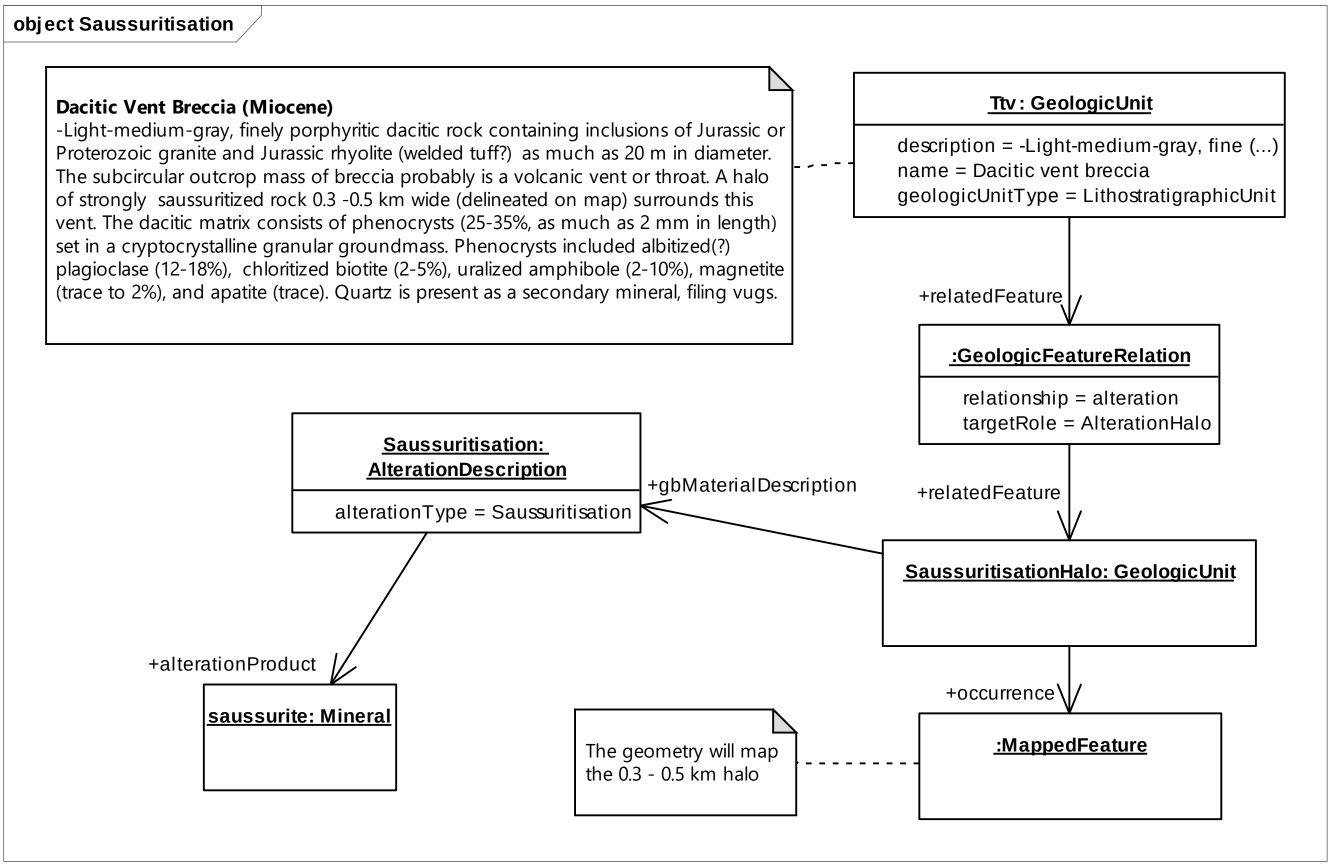


Figure 39 - Example of describing alteration halo from Drewes [3].

8.5.2.1.1 alterationType

The property `alterationType:AlterationTypeTerm` contains a term from a controlled vocabulary of alteration types (e.g., potassic, argillic, advanced argillic).

8.5.2.1.2 alterationProduct

The property `alterationProduct` is an association between the `AlterationDescripton` and `EarthMaterial` describing the material resulting from the alteration processes, e.g. alteration minerals, saprolite, ferricrete, clay, calcrete, skarn, etc. Materials observed in a soil profile could be identified using this property.

8.5.2.1.3 alterationDistribution

The `alterationDistribution` (`SWE::Category`) property describes the spatial distribution or geometry of alteration zones using a term from a controlled vocabulary. e.g., patchy, spotted, banded, veins, vein breccia, pervasive, disseminated, etc.

8.5.2.1.4 alterationDegree

The property `alterationDegree` (`SWE::Category`) contains a term from a controlled vocabulary to indicate the magnitude of observed alteration.

8.5.2.1.5 alterationEvent

The property `alterationEvent` is an association between an `AlterationDescription` and a `GeologicEvent` describing the `GeologicEvent` associated with the alteration.

8.5.2.2 ChemicalComposition

`ChemicalComposition` is a kind of `EarthMaterialDescription` that delivers the chemical composition of a geological unit or earth material, as a list of element or oxide concentrations.

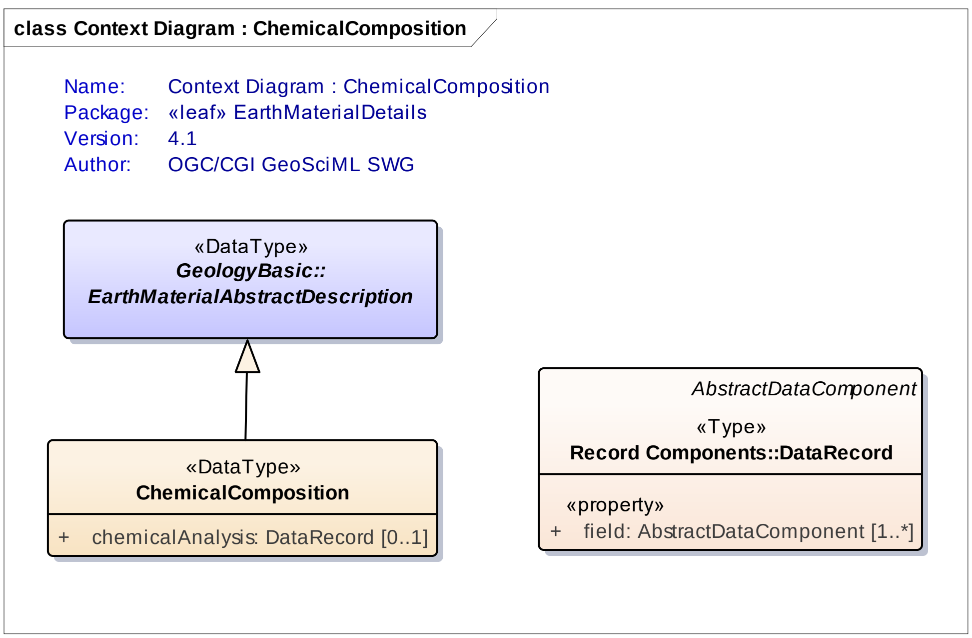


Figure 40 - Chemical composition context diagram.

8.5.2.2.1 chemicalAnalysis

The `chemicalAnalysis` property (`SWE:DataRecord`) contains a collection of geochemical results in a form of a `DataRecord` (a collection of fields composed of description and values).

8.5.2.3 CompoundMaterialDescription

The `CompoundMaterialDescription` class is a kind of `EarthMaterialDescription` that provides an extended description of a compound earth material (i.e., rocks and unconsolidated solid earth materials).

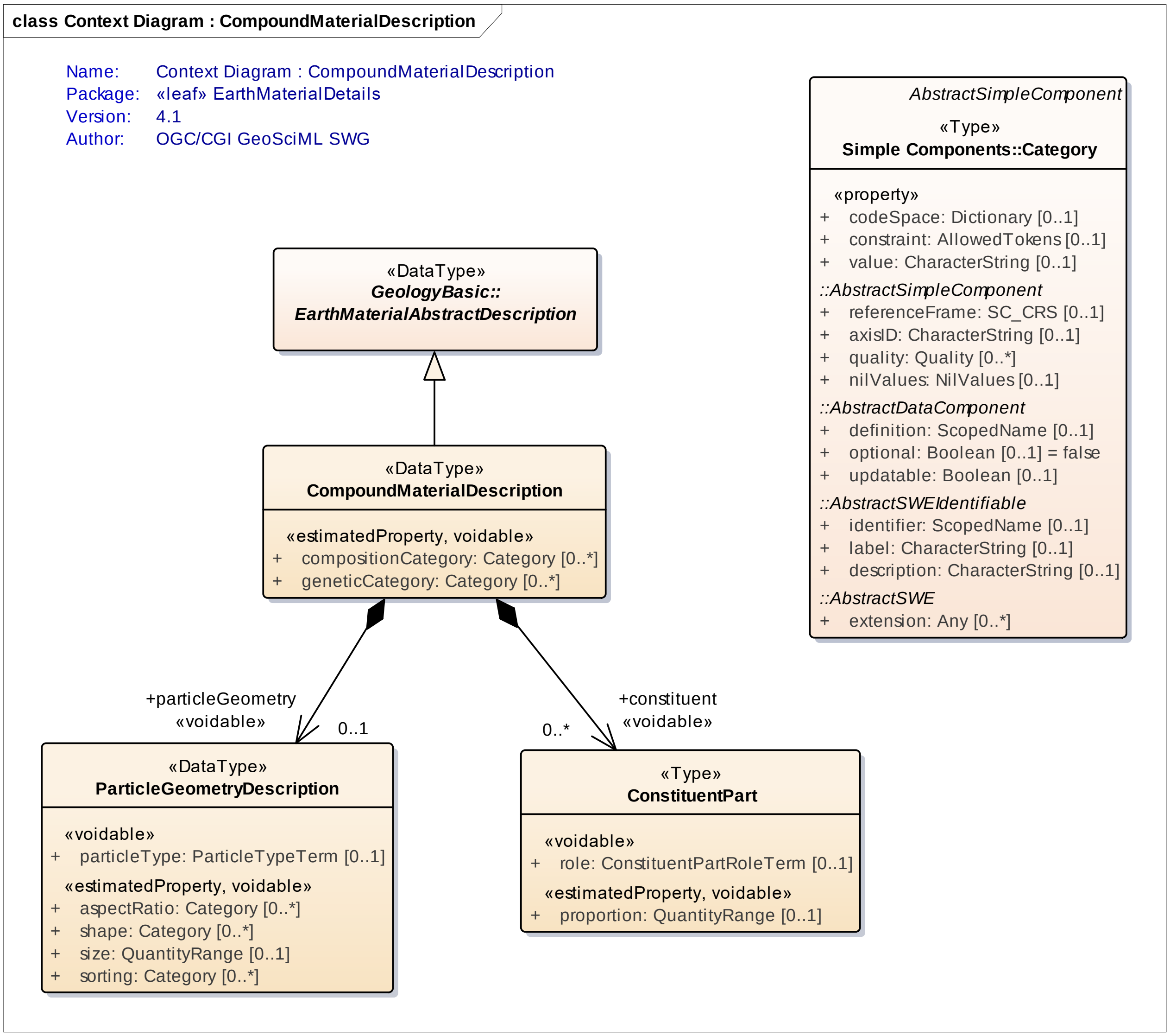


Figure 41: Compound material description context diagram.

8.5.2.3.1 compositionCategory

The `compositionCategory` property (`SWE::Category`) provides a term from a controlled vocabulary to specify the gross compositional character of a compound material. Composition as used here is loosely construed to include both chemical composition and petrographic composition, thus multiple values may be applied to a single rock, e.g. metaluminous and alkalic, undersaturated and basic, etc. Terms would typically include broad chemical classifications such as silicate, carbonate, ferromagnesian, oxide. However, this attribute may have different terminology for different kinds of rocks - for example sandstone petrographic classification terms (e.g. feldspathic) might be placed here.

8.5.2.3.2 geneticCategory

The property geneticCategory (`SWE::Category`) provides a term from a controlled vocabulary that represents a summary geologic history of the material. (i.e., a genetic process classifier term). Examples include igneous, sedimentary, metamorphic, shock metamorphic, volcanic, pyroclastic.

8.5.2.3.3 particleGeometry

The `particleGeometry:ParticleGeometryDescription` contains an instance of `ParticleGeometryDescription`.

8.5.2.3.4 constituent

The property `constituent` is an association between a `CompoundMaterialDescription` and a `ConstituentPart` that makes up part of the `CompoundMaterial`.

8.5.2.4 ParticleGeometryDescription

`ParticleGeometryDescription` describes particles in a `CompoundMaterial` independent of their relationship to each other or their orientation. It is distinguished from `Fabric` in that the `ParticleGeometryDescription` remains constant if the material is disaggregated into its constituent particles, whereas `Fabric` is lost if the material is disaggregated. Properties include the particle size (grainsize), particle sorting (size distribution, e.g., well sorted, poorly sorted, bimodal sorting), particle shape (surface rounding or crystal face development, e.g., well rounded, euhedral, anhedral), and particle aspect ratio (e.g., elongated, platy, bladed, compact, acicular).

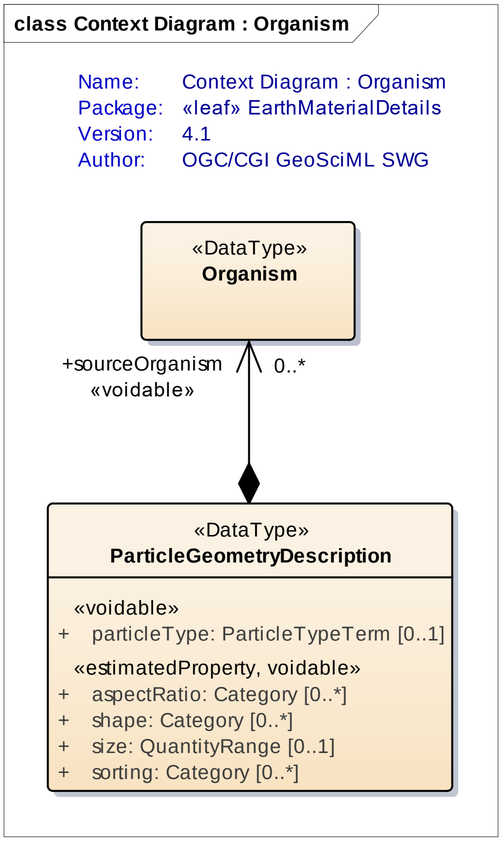


Figure 42 - ParticleGeometry context diagram.

8.5.2.4.1 particleType

The `particleType:ParticleTypeTerm` provides a term from a controlled vocabulary to specify the nature of individual particles of each constituent in an `EarthMaterial` aggregation, based mostly on their genesis. When applied on `ParticleDescription` for `CompoundMaterial`, it would characterise all particles in aggregate. Use this property on `CompoundMaterial` to distinguish rocks composed of crystals (crystalline rocks) from rocks composed of granular particles (clasts, fragments). Examples include ooliths, crystals, pore space. Constituent type is determined based on the nature of the particles, and ideally is independent of the relationship between particles in a compound material aggregation.

8.5.2.4.2 aspectRatio

The `aspectRatio` property (`SWE::Category`) contains a term from a controlled vocabulary describing the geometry of particles based on the ratios of lengths of long, intermediate and short axes of grains. It equates to sphericity in sedimentary rocks (i.e., the degree to which the shape of a particle approximates a sphere). The formal definition is "*A quantitative specification based on the ratio of lengths of long, intermediate and short axes of grain shape*" [16] [24]. (e.g., prolate, slightly flattened, very bladed, equant, acicular, tabular).

8.5.2.4.3 shape

The `shape` property (`SWE::Category`) describes,

a) the development of crystal faces bounding particles in crystalline compound materials, and
b) the surface rounding of grains in sedimentary rocks. Roundness is a measure of the sharpness of the edges between surfaces bounding a particle [10] [22].

The terms shall be a term from a controlled vocabulary and be appropriate for the kind of compound material (e.g., for crystalline rocks- euhedral, ideoblastic, subhedral, anhedral, xenoblastic; for sedimentary rocks - angular, rounded).

8.5.2.4.4 size

The property `size` (`SWE::QuantityRange`) reports the size that specifies particle grainsize. Values may be reported using absolute measurements (e.g., range, mean, median, mode, maximum).

8.5.2.4.5 sorting

The `sorting` property (`SWE::Category`) contains a term from a vocabulary that specifies the size distribution of particles in a `CompoundMaterial`. Terminology for sorting in sedimentary rocks is based on the quantitative Graphic Standard Deviation (IGSD) scheme proposed by Folk [5] [6]. Example for this attribute may include sedimentary terms such as well sorted and poorly sorted, or igneous terms such as porphyritic, equigranular, seriate.

8.5.2.4.6 sourceOrganism

The `sourceOrganism` property is an association between a `ParticleGeometryDescription` and an `Organism` that is the source of the fossil particles (sponge spicules, bivalve shells, etc.).

8.5.2.5 ConstituentPart

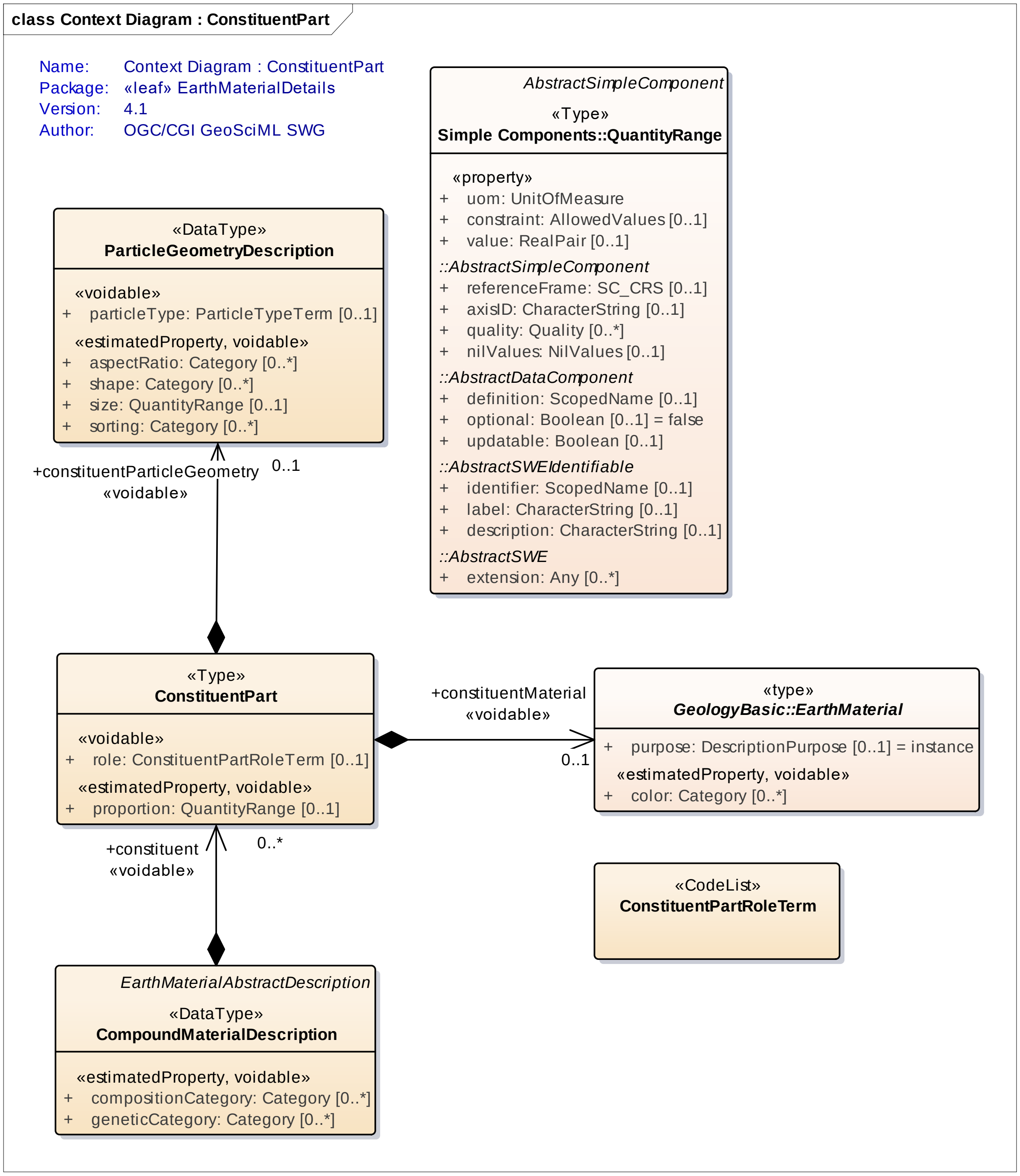


Figure 43 - ConstituentPart context diagram.

The `ConstituentPart` class describes how Earth materials may be made up of other Earth materials, including the proportion of the constituent part in the whole (e.g., 20%, minor, dominant); and the role that the constituent plays in the whole (e.g., matrix, groundmass, framework, phenocryst, xenolith, vein).

The distinction between "`role`" and "`particleType`" is subtle. An operational test is that `particleType` may be determined independent of relationship between particles in the aggregation, whereas role requires consideration of the relationship to other particles. A particle may be identified as a clast, independent of its material composition, and independent of its relationship to other grains in a rock. The term 'floating clast' is a `role`, because it is dependent on the relationship 'not in contact with other clasts'. Readers should consider Dunham's textural classification of carbonate rocks (wackestone, packstone, grainstone, etc.) in the description of carbonate rocks [4]. The description is predicated on identification of two kinds of intraclasts (grains) and matrix (carbonate mud), and then uses this distinction to establish relationships--mud supported vs. grain supported -- that define roles for the two types of constituents (framework, matrix...).

8.5.2.5.1 role

The `role:ConstituentPartRoleTerm` property contains a term from a controlled vocabulary that describes the role a `ConstituentPart` plays in a `CompoundMaterial` aggregation. The same `EarthMaterial` may occur as different `ConstituentParts` playing different roles within one `CompoundMaterial`. For example, feldspar may be present as groundmass ("groundmass" is a `ConstituentPart::role`) and as phenocrysts ("phenocryst" is another `ConstituentPart::role`) within a single igneous rock.

8.5.2.5.2 proportion

The `proportion` property (`SWE::QuantityRange`) reports the fraction of the whole that is formed by a ConstituentPart in a part/whole relationship. It is used for the `ConstituentPart` portion in a `CompoundMaterial`. It specifies the fraction of the `EarthMaterial` formed by the part (e.g., 20%, minor, dominant).

8.5.2.5.3 constituentMaterial

The `constituentMaterial` property is an association between a `ConstituentPart` and an `EarthMaterial` that specifies the `EarthMaterial` that is forming the `ConstituentPart`.

8.5.2.6 FabricDescription

The `FabricDescription` data type describes all types of fabrics associated with a `CompoundMaterial` (i.e., tectonic, metamorphic, sedimentary, igneous fabrics or textures). It denotes a pattern, defined by one or more `CompoundMaterial` constituents, that is present throughout a rock body when considered at some scale. `FabricDescription` is defined based on the average configuration of many constituents. Penetrative fabric denotes that these constituents are distributed throughout the rock volume at the scale of observation [15], and are repeated at distances that are small relative to the scale of the whole, such that they can be considered to pervade the whole uniformly ([19] p. 21-24; [7] p. 73; [10],[15]).

`FabricDescription` is distinguished from `ParticleGeometry` based on the criteria that particle geometry is preserved if a `CompoundMaterial` is disaggregated, while `FabricDescription` is not defined if the material is disaggregated.

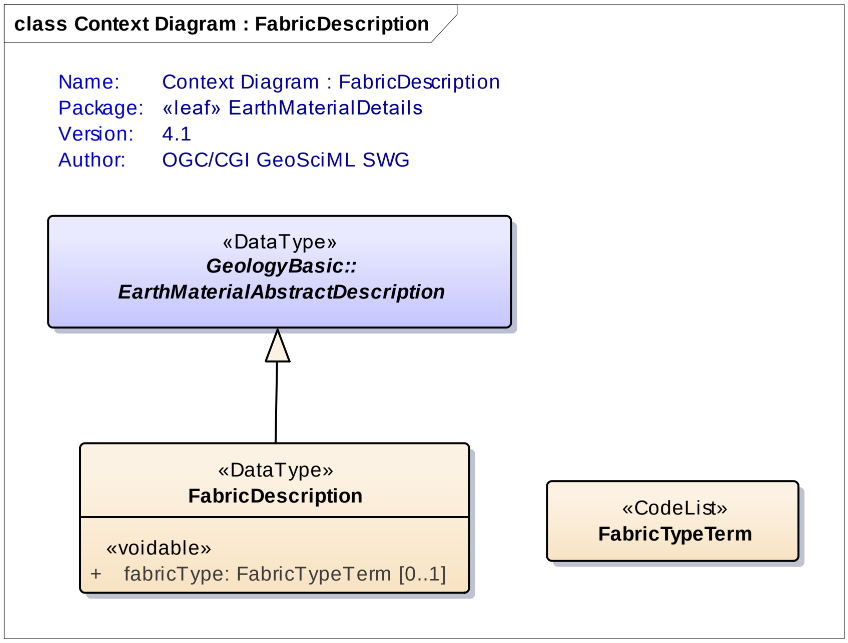


Figure 44 - Fabric description context diagram.

8.5.2.6.1 fabricType

The `fabricType:FabricTypeTerm` property contains a term from a controlled vocabulary to denote the type of fabric in the `CompoundMaterial` (e.g., rapikivi texture, autobrecciation, spaced cleavage, porphyroblastic, cross-bedding). The `fabricType` describes a pattern, defined by one or more `CompoundMaterial` constituents, that is present throughout a rock body when considered at some scale. It is defined based on the average configuration of many constituents. Penetrative fabric denotes that these constituents are distributed throughout the rock volume at the scale of observation [15], and are repeated at distances that are small relative to the scale of the whole, such that they can be considered to pervade the whole uniformly.

8.5.2.7 InorganicFluid

An inorganic fluid is a non-crystalline `EarthMaterial` (solid, liquid, or gas) that tends to flow or conform to the shape of its container (examples: water, brine, glass).. By convention liquid mercury is considered a mineral. This class is an empty placeholder for extension at a later date, or by other domain models.

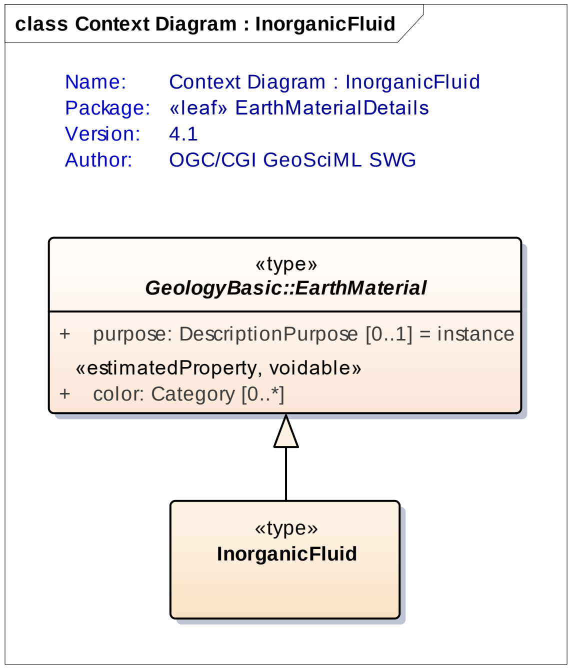


Figure 45 - Inorganic fluid context diagram.

8.5.2.8 MetamorphicDescription

The data type `MetamorphicDescription` describes the character of metamorphism applied to a `CompoundMaterial` or `GeologicUnit` using one or more properties including estimated intensity (grade; e.g. high grade, low grade), characteristic metamorphic mineral assemblages (facies; e.g., greenschist, amphibolite), peak P-T estimates, and protolith material if known. A `MetamorphicDescription` provides a link to the `GeologicEvent` associated to the metamorphic event.

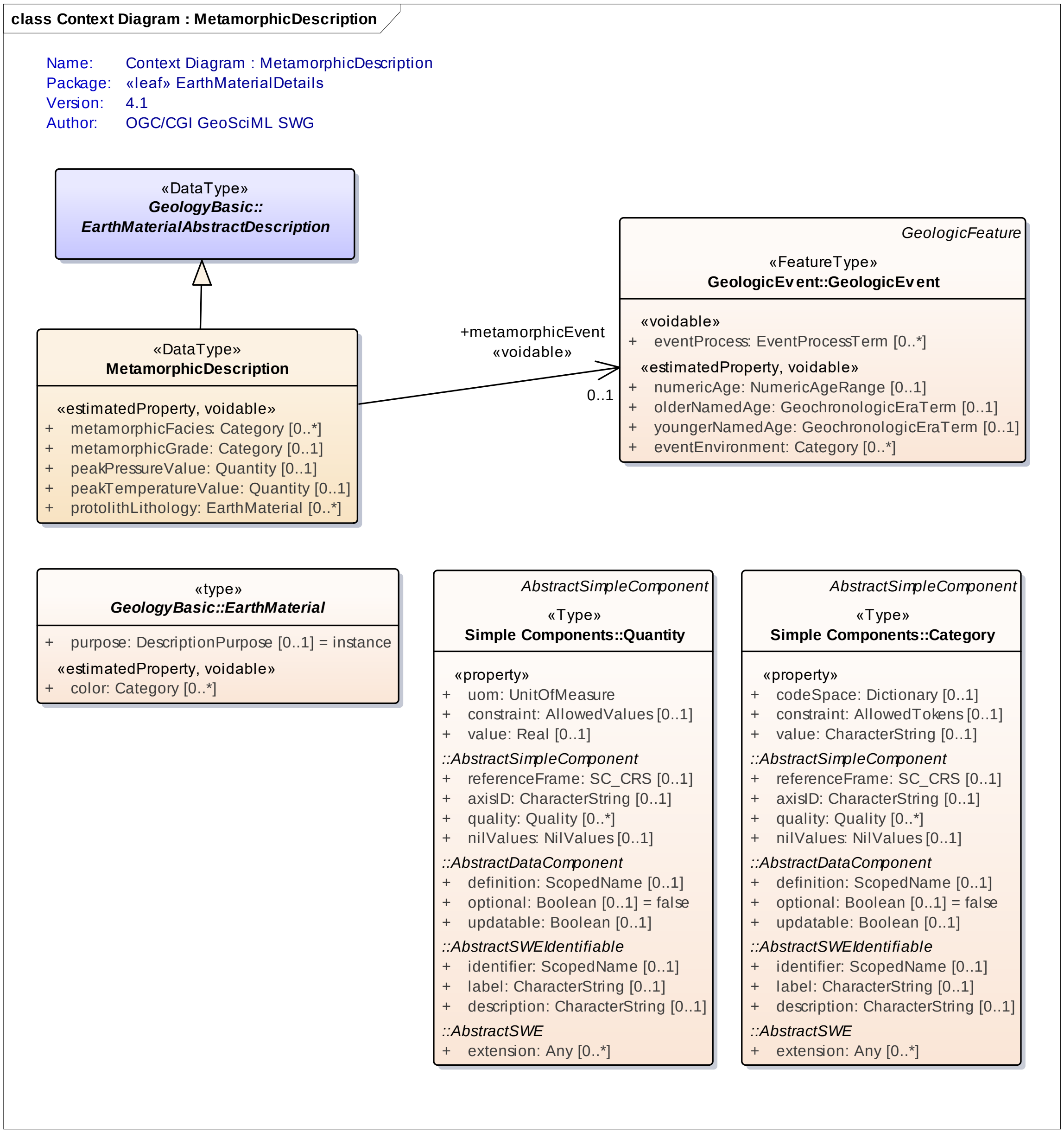


Figure 46 - Metamorphic description context diagram.

8.5.2.8.1 metamorphicFacies

The `metamorphicFacies` property (`SWE::Category`) contains a term from a controlled vocabulary that describes a characteristic mineral assemblages indicative of certain metamorphic pressure and temperature conditions. Examples include Barrovian metasedimentary zones (e.g., biotite facies, kyanite facies) or assemblages developed in rocks of more mafic composition (e.g., greenschist facies, amphibolite facies).

8.5.2.8.2 metamorphicGrade

The `metamorphicGrade` property (`SWE::Category`) contains a term from a controlled vocabulary that indicates the intensity or rank of metamorphism applied to an `EarthMaterial` (e.g., high metamorphic grade, low metamorphic grade).

It indicates in a general way the pressure-temperature (PT) environment in which the metamorphism took place. The determination of metamorphic grade is based on mineral assemblages (i.e., facies) present in a rock that are interpreted to have crystallized in equilibrium during a particular metamorphic event.

8.5.2.8.3 peakPressureValue

The `peakPressureValue` property (`SWE::Quantity`) reports a numerical value to indicate the estimated pressure at peak metamorphic conditions.

8.5.2.8.4 peakTemperatureValue

The `peakTemperatureValue` property (`SWE::Quantity`) reports a numerical value to indicate the estimated temperature at peak metamorphic conditions.

8.5.2.8.5 protolithLithology

The `protolithLithology` is an association between a `MetamorphicDescription` and an `EarthMaterial` that describes the pre-metamorphic lithology for a metamorphosed `CompoundMaterial`.

8.5.2.8.6 metamorphicEvent

The `metamorphicEvent` property is an association between a `MetamorphicDescription` and a `GeologicEvent` that denotes the age, environment and process associated with a particular metamorphic assemblage in a `GeologicUnit`.

8.5.2.9 OrganicMaterial

`OrganicMaterial` is an `EarthMaterial` that belongs to the class of chemical compounds having a reduced carbon basis (as distinct from carbonates), and derived from living organisms. It includes high-carbon `EarthMaterials` such as bitumen, peat, and coal. This class is an empty placeholder for extension at a later date, or by other domain models.

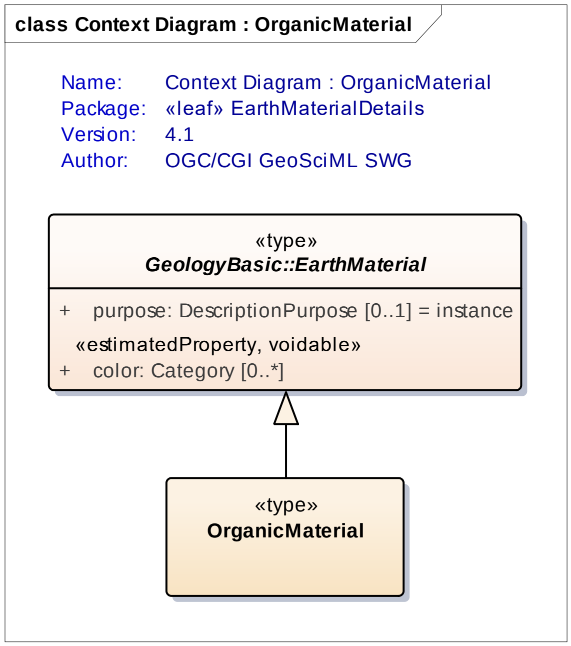


Figure 47 - Organic material context diagram.

8.5.2.10 Organism

`Organism` is a broad class to represent any living or once living things. This is the connection to taxonomy/biology for fossils. This class is an empty placeholder for extension at a later date, or by other domain models.

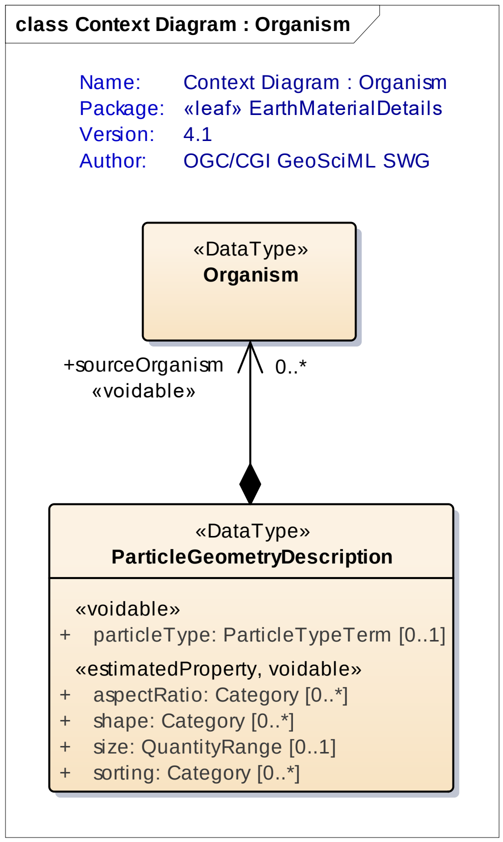


Figure 48 - Organism context diagram.

8.5.2.11 PhysicalDescription

`PhysicalDescription` is a class that describes the numeric physical properties of a geologic unit (`GeologicUnit` 8.4.1.3), earth material (`EarthMaterial` 8.4.1.6), or geologic structure (`GeologicStructure` 8.4.3.1). (e.g., density, porosity, magnetic susceptibility, remanent magnetism). These properties are modelled here as scalar numeric values (`SWE::Quantity`).

Vector and tensor physical properties are considered to be more applicable to located observations and should be delivered as `OM_Observations` with associated geologic unit or geologic structure features. Since PhysicalProperty can be an arbitrary property, it satisfies the requirements of clause 7.2.2.8 or OGC 10-004r3 that states that "*The observed property shall be a phenomenon associated with the feature-of-interest.*", and hence any `GeologicUnit`, `GeologicStructure` are valid features of interest for any `OM_Observation`.

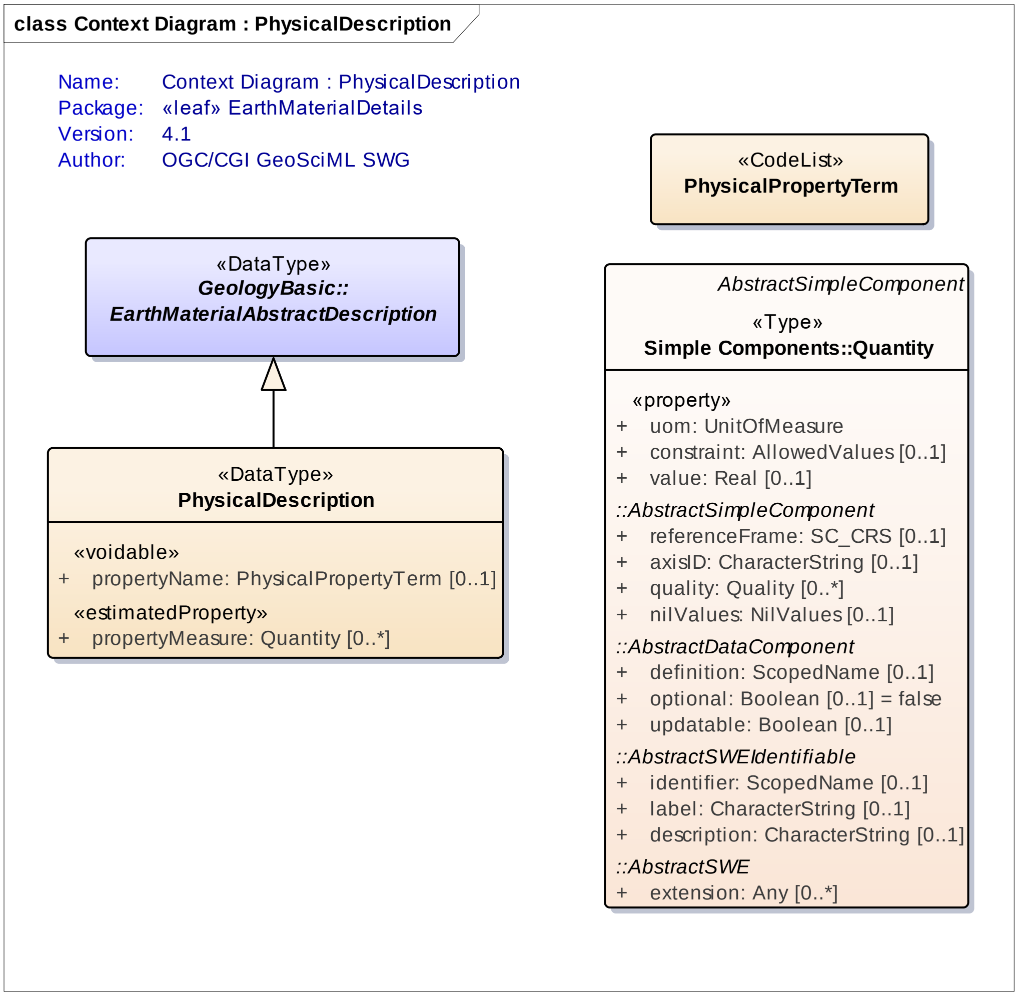


Figure 49 - Physical description context diagram.

8.5.2.11.1 propertyName

The property `propertyName:PhysicalPropertyTerm` contains a term from a controlled vocabulary of physical properties of rock materials (e.g., density, porosity, magnetic susceptibility, remnant magnetism, permeability, seismic velocity).

8.5.2.11.2 propertyMeasure

The `propertyMeasure` property (`SWE::Quantity`) is a scalar measurement of the physical property of a rock material, unit or structure.

8.5.2.12 RockMaterialDescription

`RockMaterialDescription` provides extended description of `RockMaterial`.

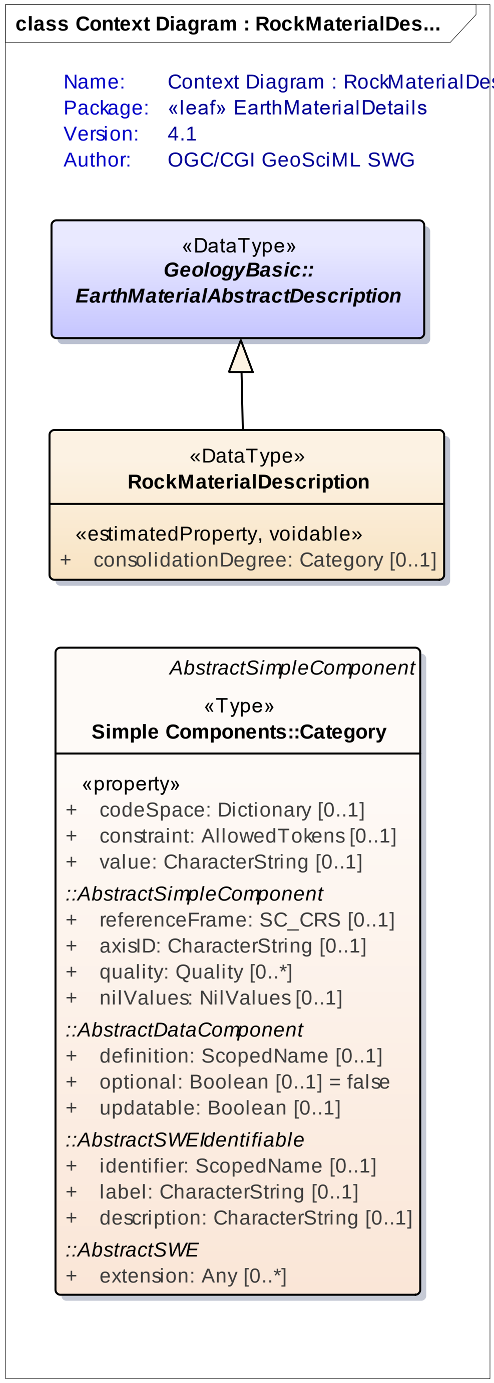


Figure 50 - Rock material description context diagram.

8.5.2.12.1 consolidationDegree

The `consolidationDegree` property (`SWE::Category`) contains a term from a controlled vocabulary that specifies the degree to which an aggregation of

`EarthMaterial` particles is a distinct solid material. Consolidation and induration are related concepts specified by this property. They define a continuum from unconsolidated material to very hard rock. Induration is the degree to which a consolidated material is made hard, operationally determined by how difficult it is to break a piece of the material. Consolidated materials may have varying degrees of induration [13].

8.5.3 GeologicAgeDetails

`GeologicEventDescription` provides extended description of geologic events through links to `GeochronologicEras` in the GeologicTimescale model. GeoSciML Basic provides terms whereas GeoSciML Extension provides a fuller ontology to describe geochronology (see 0).

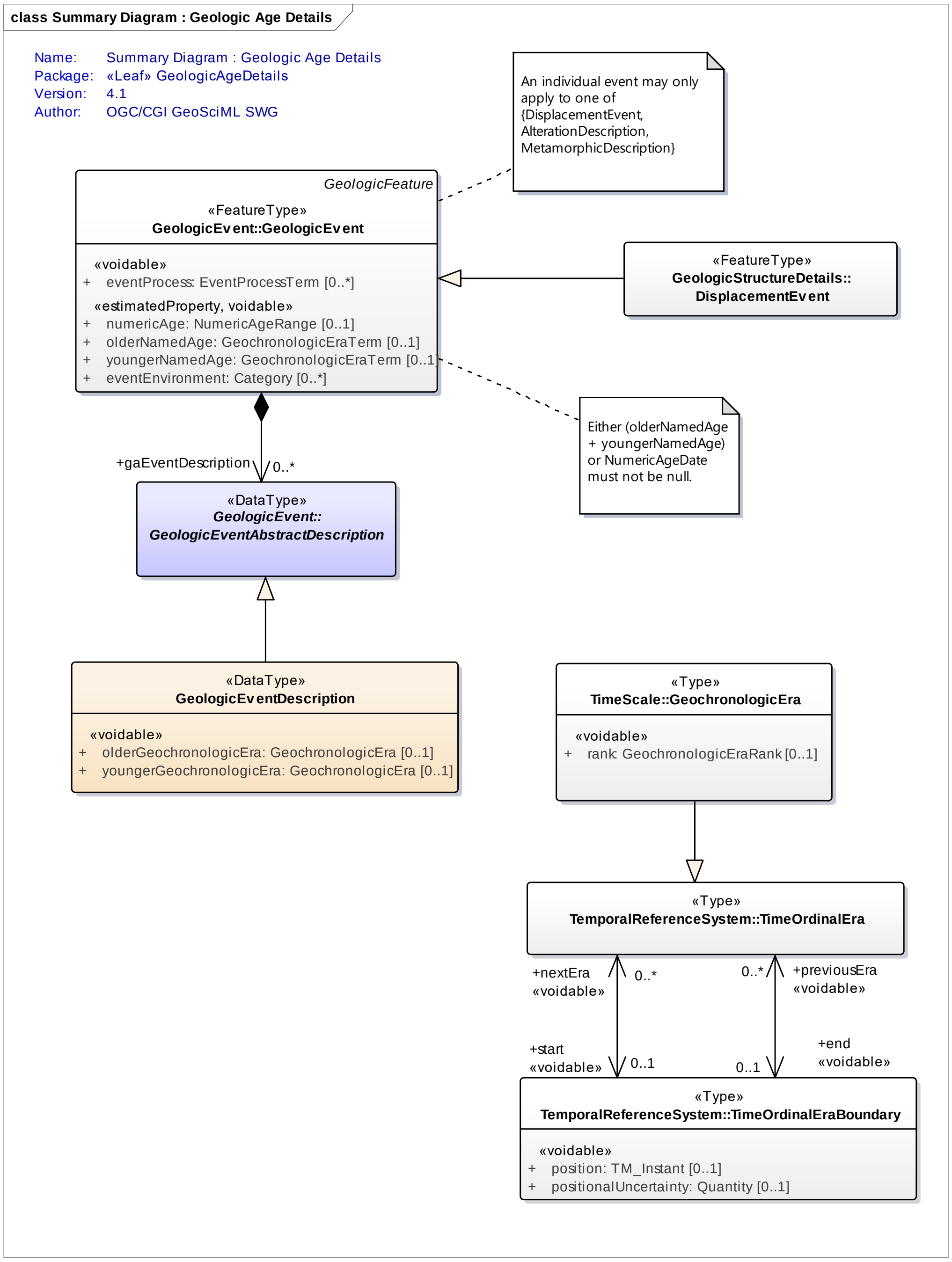


Figure 51 - GeologicAgeDetails summary diagram.

8.5.3.1 olderGeochronologicEra

The `olderGeochronologicalEra` property is an association between a `GeologicEventDescription` and a `GeochronologicEra` that corresponds to the older estimated age of a geologic feature.

8.5.3.2 youngerGeochronologicEra

The youngerGeochronologicEra property is an association between a `GeologicEventDescription` and a `GeochronologicEra` that corresponds to the younger estimated age of a geologic feature.

8.5.4 GeologicStructureDetails

The Geologic Structure Details package provides for extended descriptions of geologic structures.

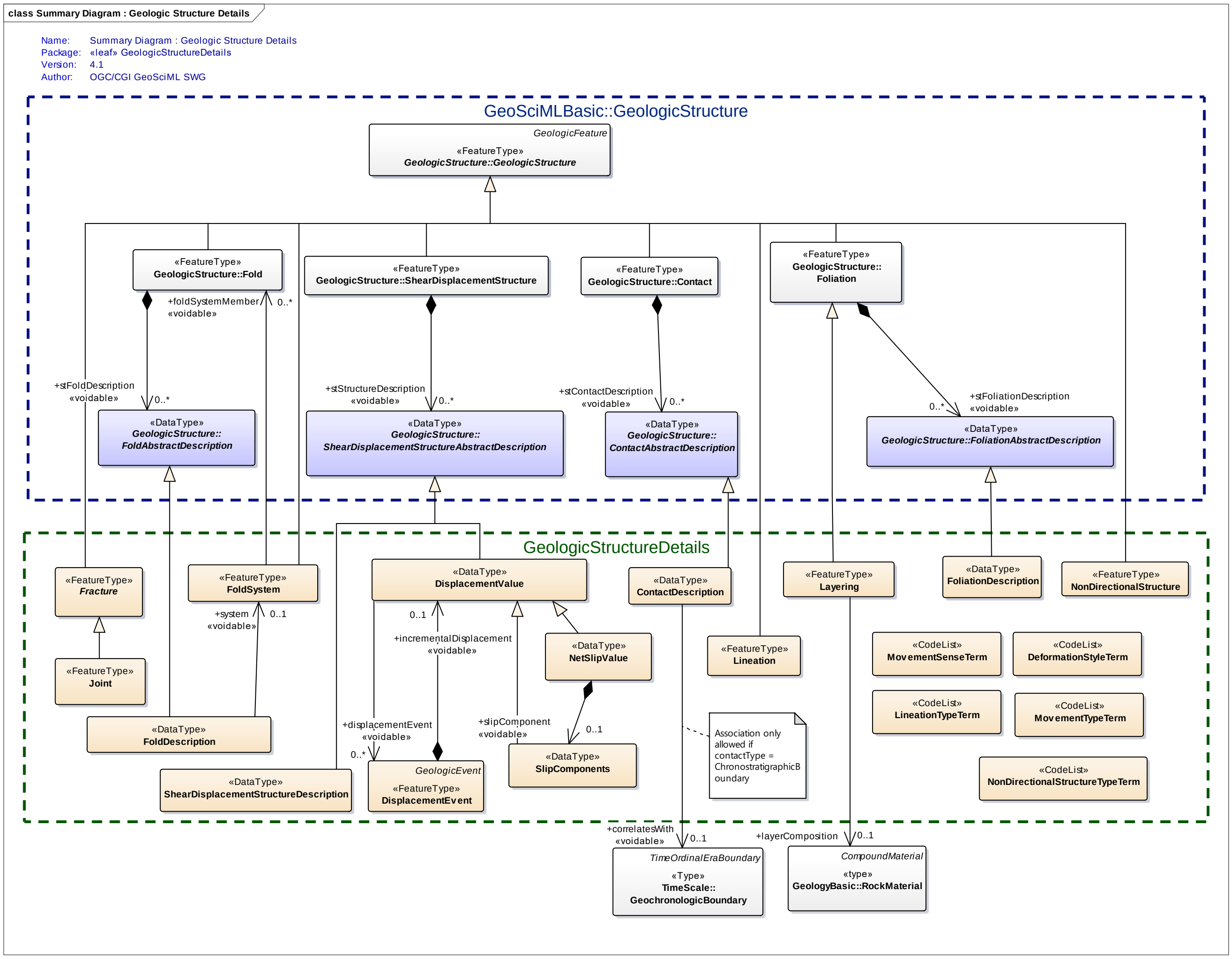


Figure 52 - Summary diagram for GeologicStructureDetails.

8.5.4.1 ContactDescription

The `ContactDescription` provides extended descriptive properties of a geologic contact. If the contact type is `ChronostratigraphicBoundary`, it can be associated with a geochronologic (i.e., time zone) boundary that may correlate with it.

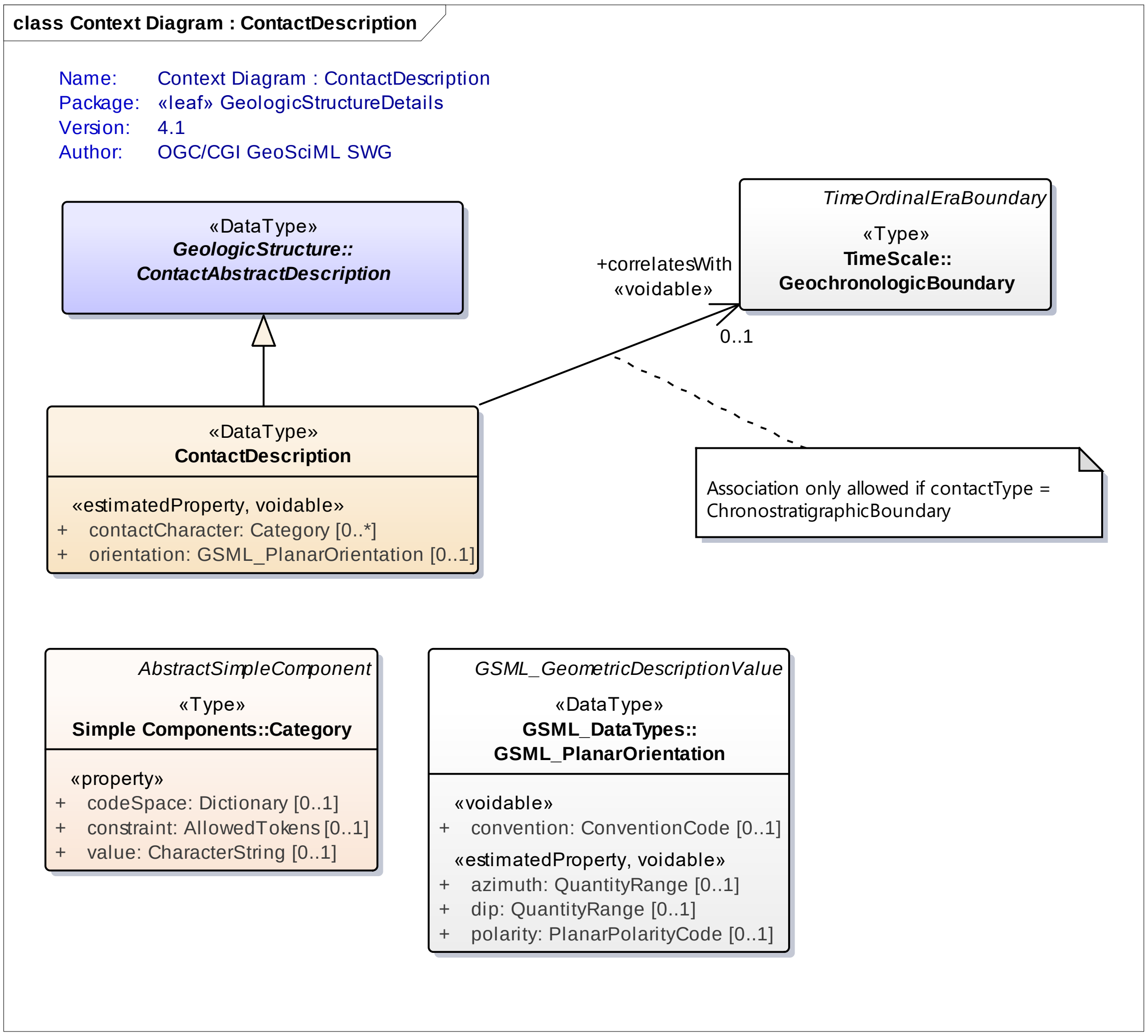


Figure 53 - ContactDescription context diagram.

8.5.4.1.1 contactCharacter

The `contactCharacter` (`SWE::Category`) contains a term from a controlled vocabulary that describes the character of the boundary (e.g. abrupt, gradational), as opposed to its type.

8.5.4.1.2 orientation

The `orientation:GSML_PlanarOrientation` property reports the general orientation of the contact surface.

8.5.4.1.3 correlatesWith

The `correlatesWith` property is an association between `ContactDescription` and a `GeochronologicBoundary` describing a geochronologic (i.e., time zone) boundary that may correlate with it. Therefore, a contact correlation with a `GeochronologicBoundary` SHALL ONLY be allowed when the `contactType` is a `ChronostratigraphicBoundary`.

/req/gsml4-extension/contact-chronoboundary	`correlatesWith` association to a `GeochronologicBondary` SHALL be allowed only when `contactType` = ChronostratigraphicBoundary.

8.5.4.2 DisplacementEvent

A displacement event is a description of the age, environment and process of a shear displacement event.

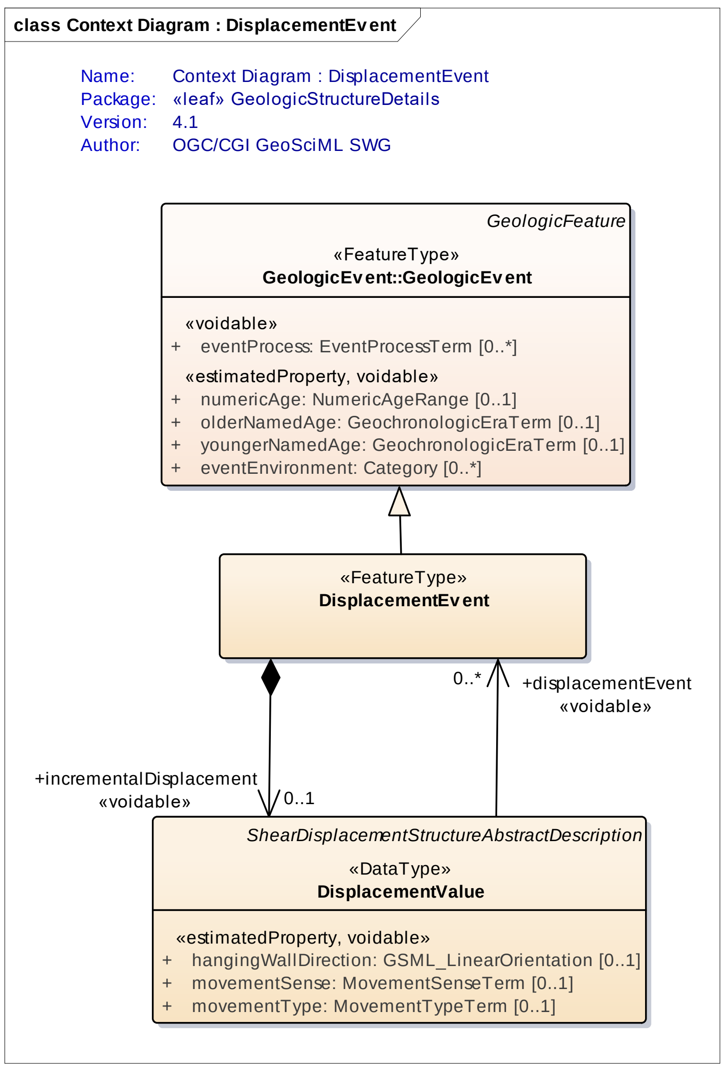


Figure 54 - DisplacementEvent context diagram

8.5.4.2.1 incrementalDisplacement

The `incrementalDisplacement:DisplacementValue` property contains a `DisplacementValue` (0) reporting the parameters of the displacement.

8.5.4.3 Layering

A planar foliation is defined by a tabular succession of layers > 5 mm thick. This definition is based on the proposed definition of gneiss by the NADM Science Language Technical Team [13]. The `GeologicStructure` characteristic of gneiss is layering.

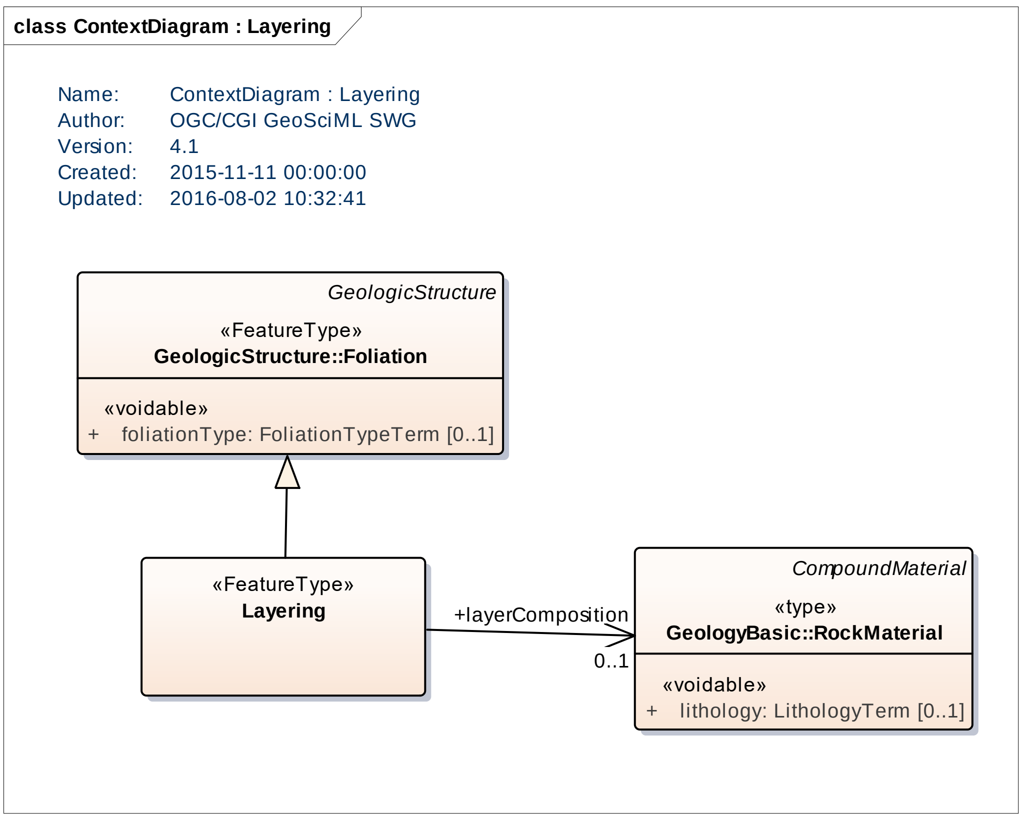


Figure 55 - Layering context diagram

8.5.4.3.1 layerComposition

The `layerComposition` property is an association between a `Layering` and a `RockMaterial` that describes the rock material that may define compositional layering.

8.5.4.4 DisplacementValue

A displacement value expresses the displacement on a fault with respect to a planar approximation of its shape.

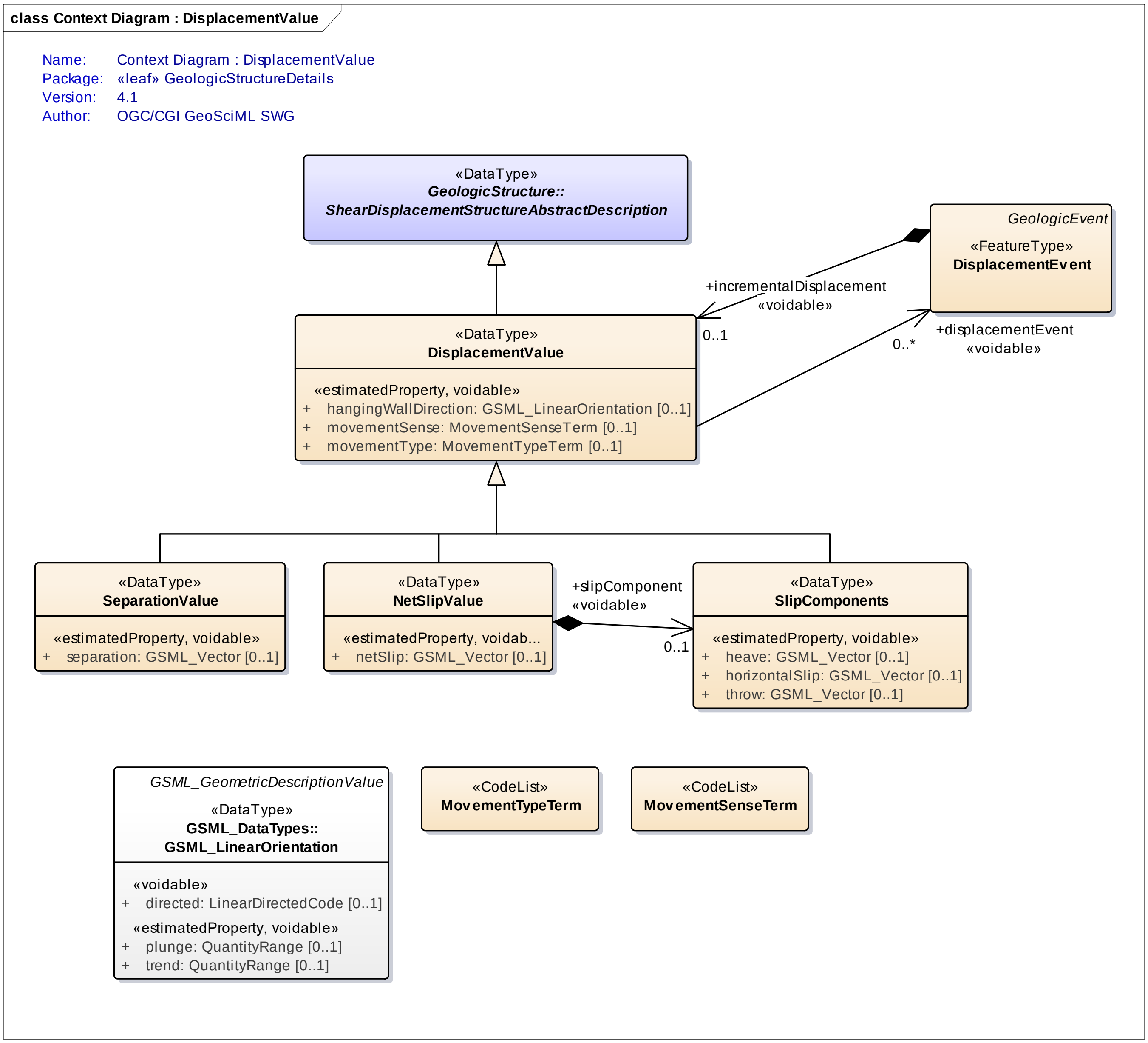


Figure 56 - Displacement value subtypes context diagram.

8.5.4.4.1 hangingWallDirection

The property `hangingWallDirection:GSML_LinearOrientation` describes the direction of the hanging-wall side of the fault or fault-system where they are steep enough to define a hanging-wall on the map trace.

8.5.4.4.2 movementSense

The property `movementSense:MovementSenseTerm` contains a term from a controlled vocabulary that describes the movement sense of displacement along a geologic structure (e.g., dextral, sinistral).

8.5.4.4.3 movementType

The property `movementType:MovementTypeTerm` contains a term from a controlled vocabulary that defines the type of movement on a shear displacement structure (e.g. dip-slip, strike-slip).

8.5.4.4.4 displacementEvent

The property `displacementEvent` is an association between a `Displacement` and a `GeologicEvent` that contains a description of the age, environment and process of a shear displacement event.

8.5.4.5 SeparationValue

`SeparationValue` is a kind of `DisplacementValue` that describes the amount of separation displacement across a structure.

8.5.4.5.1 separation

The property `separation:GSML_Vector` reports the apparent offset across a planar feature, reported as a vector.

8.5.4.6 NetSlipValue

`NetSlipValue` is a kind of `DisplacementValue` that describes the total amount of slip displacement along a structure.

8.5.4.6.1 netSlip

The property `netSlip:GSML_Vector` reports the value of the net slip, expressed as a vector.

8.5.4.6.2 slipComponent

The `slipComponent:SlipComponents` property associates the individual slip components with the net slip values.

8.5.4.7 SlipComponents

`SlipComponents` is a kind of `DisplacementValue` that is a representation of slip as a vector resolved into components within a reference frame in which horizontal axes are parallel and perpendicular to the strike of the fault. At least one of heave, horizontalSlip, or throw must not be null.

/req/gsml4-extension/slipComponents-slip	`SlipComponents` SHALL have at least one of heave, horizontalSlip or throw be a non-null value.

8.5.4.7.1 heave

The property `heave:GSML_Vector` contains a component of slip in the horizontal, and perpendicular to the strike of the fault.

8.5.4.7.2 horizontalSlip

The property `horizontalSlip:GSML_Vector` contains a slip component that is horizontal and parallel to strike of the fault.

8.5.4.7.3 throw

The property `throw:GSML_Vector` contains the vertical component of slip.

8.5.4.8 FoldDescription

`FoldDescription` is an extended descriptive property of a fold structure.

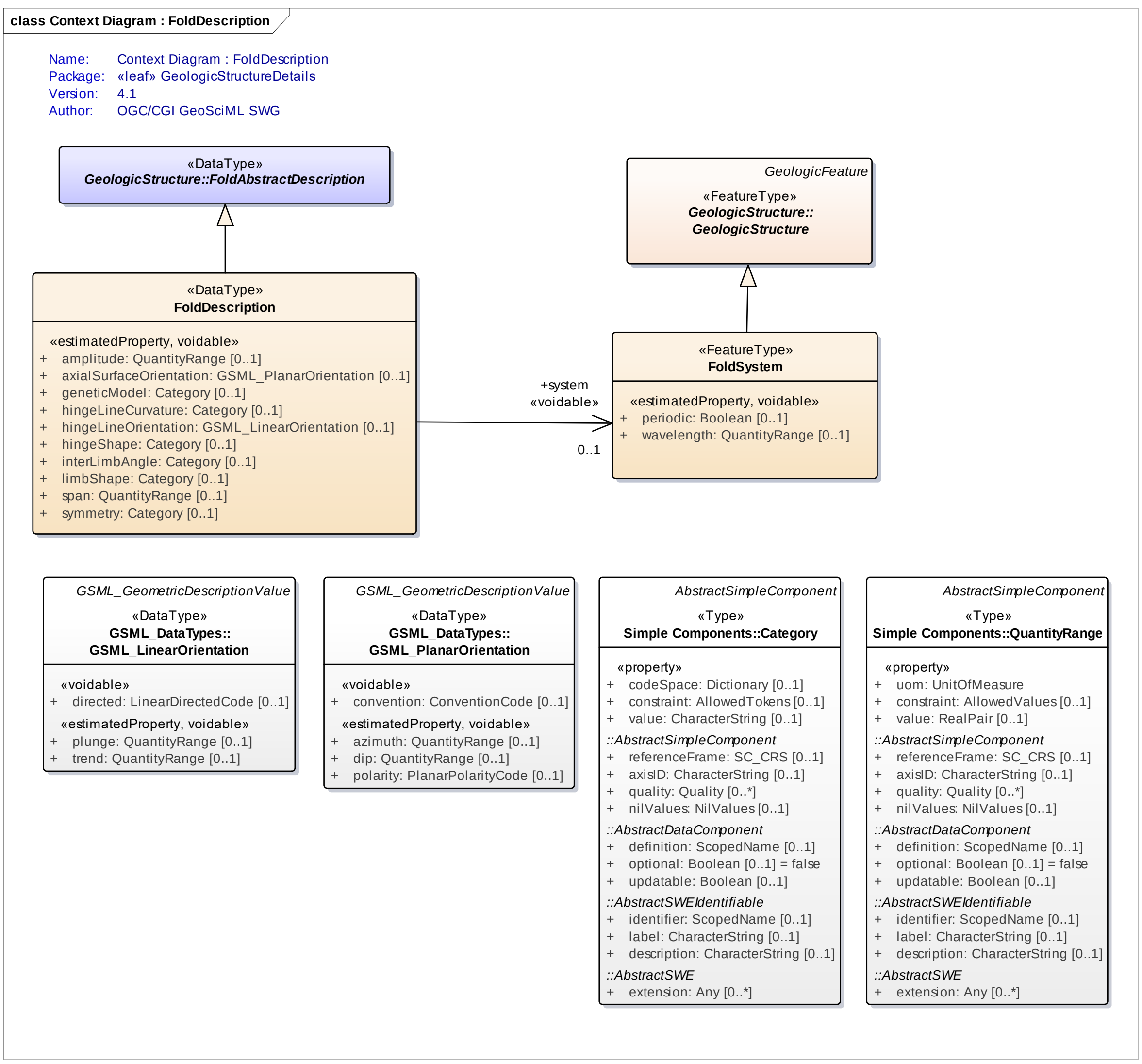


Figure 57 - FoldDescription context diagram.

8.5.4.8.1 amplitude

The `amplitude` property (`SWE::QuantityRange`) reports the length from line segment connecting inflection points on adjacent fold limbs to the intervening fold hinge.

8.5.4.8.2 axialSurfaceOrientation

The property `axialSurfaceOrientation:GSML_PlanarOrientation` is used to characterize the geometry of a fold. The axial surface of a particular fold may be located based on observations of the folded geologic structure, but in general it has no direct physical manifestations. As a geologic surface, it has geometric properties, including orientation, which may be specified by observations at one or more locations, or generalized using terminology (upright, inclined, reclined, recumbent, overturned). Dip and Dip Direction are one approach to specifying the value.

8.5.4.8.3 geneticModel

The property `geneticModel` (`SWE::Category`) contains a term from a controlled vocabulary describing the specification of genetic model for fold, e.g. flexural slip, parallel.

8.5.4.8.4 hingeLineCurvature

The `hingeLineCurvature` property (`SWE::Category`) contains a term from a controlled vocabulary that describes the variation in orientation of fold hinge along trend of fold, distinguishing sheath from cylindrical folds (e.g. sheath, dome, basin, cylindrical.).

8.5.4.8.5 hingeLineOrientation

The property `hingeLineOrientation:GSML_LinearOrientation` reports the specification of the hinge line orientation for fold. `GSML_LinearOrientation` allows for a term value specification or a numeric specification of either or both the trend and plunge of hinge line. Hinge plunge term examples: sub-vertical, steeply plunging, sub-horizontal, reclined and vertical for special cases in which hinge plunge is close to axial surface dip. 0..* cardinality allows for both a numeric specification and a term specification.

8.5.4.8.6 hingeShape

The property `hingeShape` (`SWE::Category`) reports a term from a controlled vocabulary describing the hinge shape, e.g. Rounded vs. angular hinge zones. This property has to do with the proportion of the wavelength that is considered part of hinge.

8.5.4.8.7 interLimbAngle

The property `interLimbAngle` (`SWE::Category`) contains a term from a controlled vocabulary describing the interlimb angle using a tightness term (e.g. gentle (120-180°), open (70-120°), close (30-70°), tight (10-30°), isoclinal (0-10°)).

8.5.4.8.8 limbShape

The `limbShape` property (`SWE::Category`) contains a term from a controlled vocabulary describing the shape of the limb (e.g. straight vs curved limbs, kink, chevron, sinusoidal, box).

8.5.4.8.9 span

The `span` property (`SWE::QuantityRange`) reports a value describing the linear distance between inflection points in a single fold.

8.5.4.8.10 symmetry

The `symmetry` property (`SWE::Category`) contains a term from a controlled vocabulary describing the concordance or discordance of bisecting surface and axial surface, or the ratio of length of limbs. The folded surface may have asymmetry defined by limb length ratio if inflection points are defined. The definition based on bisecting surface/axial surface angle depends on having multiple surfaces defined such that the axial surface may be identified (symmetric, asymmetric).

8.5.4.8.11 system

The `system` property is an association between a `FoldDescription` and a `FoldSystem` that aggregates folds into a system.

8.5.4.9 FoldSystem

A `FoldSystem` is a collection of congruent folds (axis and axial surface are parallel) produced by the same tectonic event. It is sometimes referred to as a "fold train".

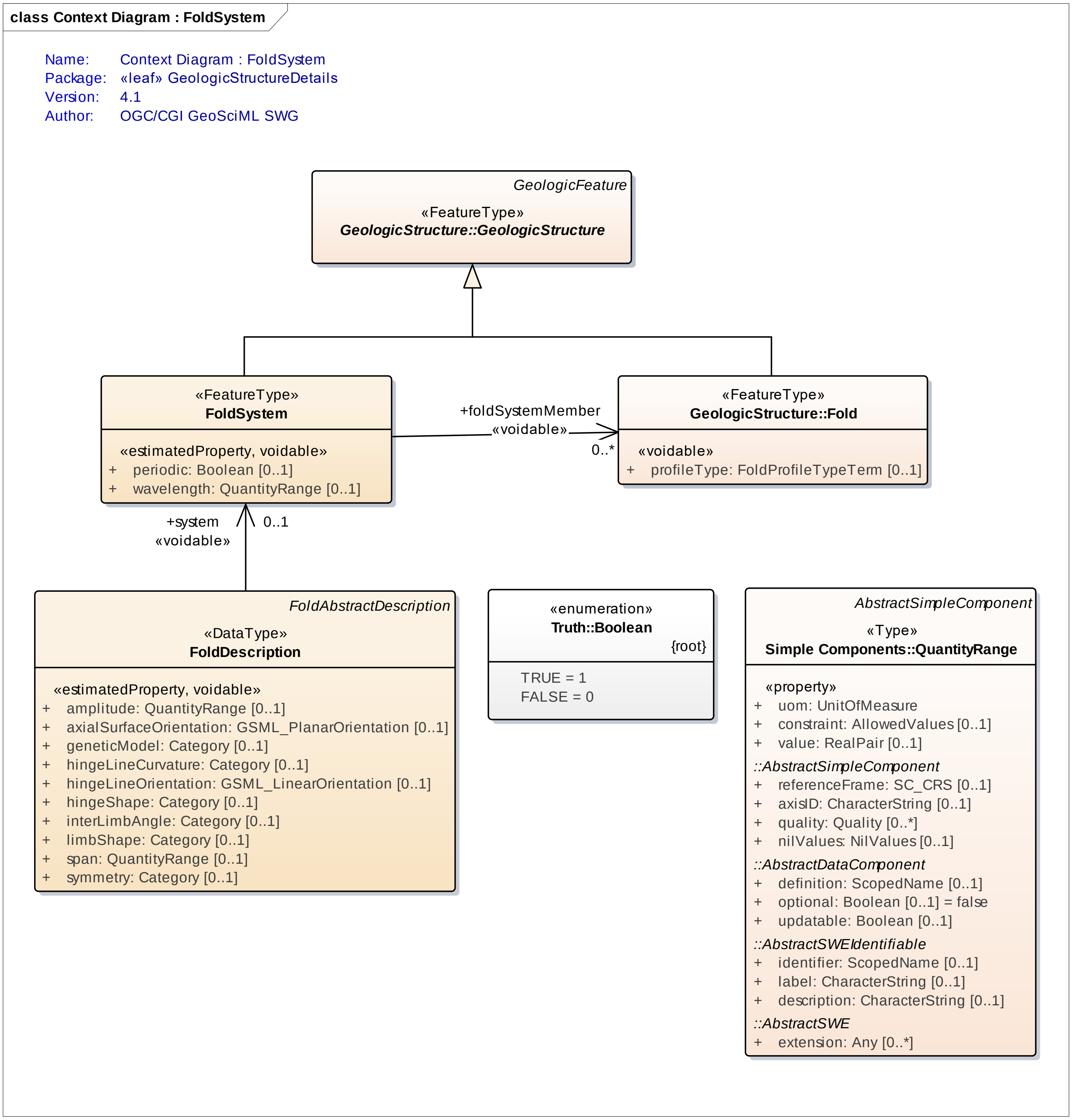


Figure 58 - FoldSystem context diagram.

8.5.4.9.1 periodic

The property `periodic:Primitive::Boolean` reports TRUE if the hinges in a train are regularly spaced, and FALSE otherwise.

8.5.4.9.2 wavelength

The property `wavelength` (`SWE::QuantityRange`) contains a quantitative description of the length between adjacent antiforms (or synforms) in a fold train.

8.5.4.9.3 foldSystemMember

The `foldSystemMember` is an association between a `FoldSystem` and the `Folds` that are members of that system.

8.5.4.10 FoliationDescription

`FoliationDescription` provides extended descriptive properties for a foliation structure.

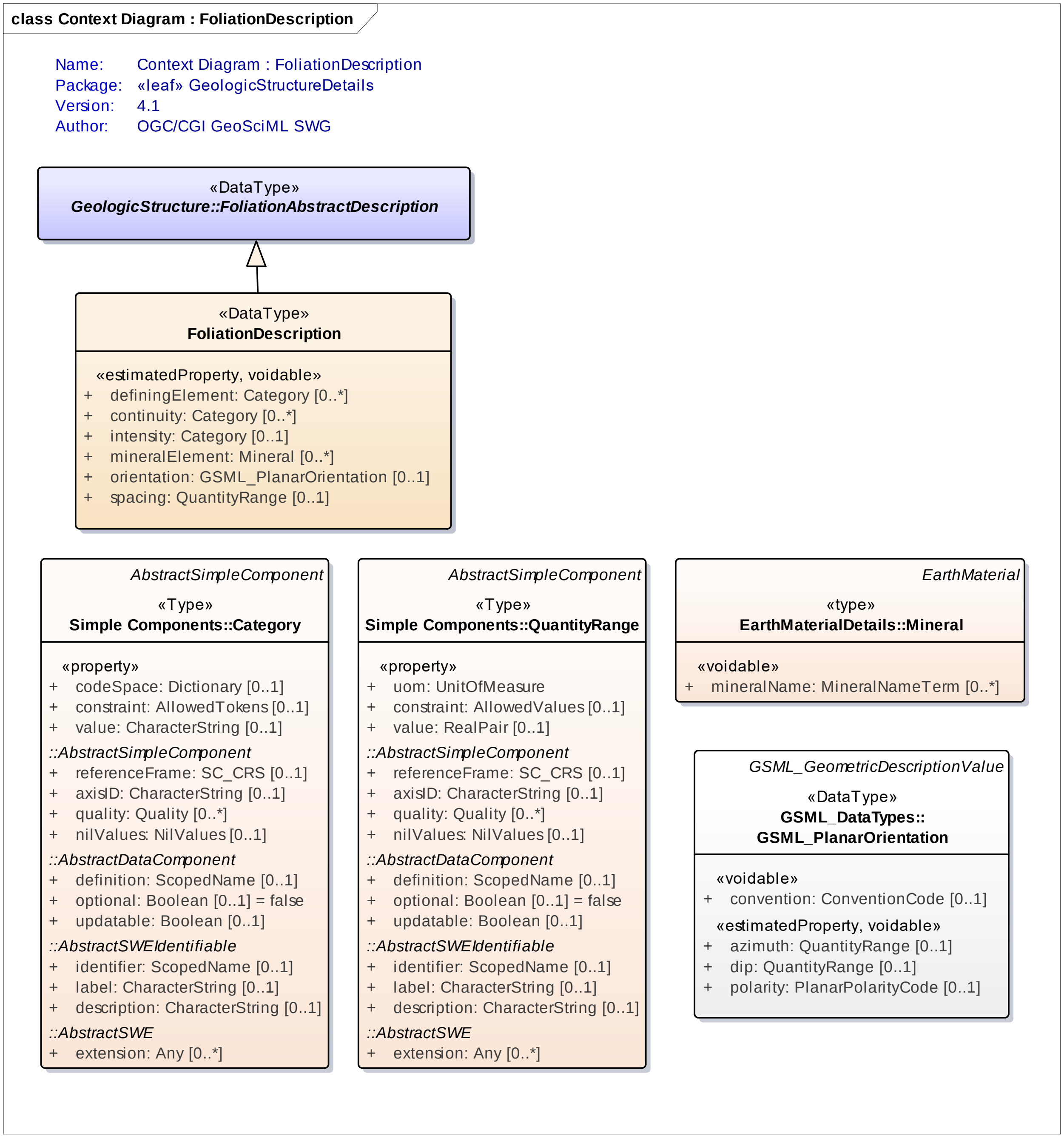


Figure 59 - FoliationDescription context diagram.

8.5.4.10.1 definingElement

The property `definingElement` (`SWE::Category`) contains a term from a controlled vocabulary describing the kinds of inhomogeneity in a rock body that may define a

GeologicStructure. Examples include discontinuity, shaped surface, oriented particle, material boundary, and layer.

8.5.4.10.2 continuity

The continuity property (SWE::Category) reports a term from a controlled vocabulary to distinguish continuous vs. disjunct cleavages.

8.5.4.10.3 intensity

The intensity property (SWE::Category) contains a term from a controlled vocabulary to describe how well the foliation is developed (e.g., weak, moderate, strong).

8.5.4.10.4 mineralElement

The mineralElement property is an association between FoliationDescription and a Mineral that defines that foliation.

8.5.4.10.5 orientation

The orientation:GSML_PlanarOrientation contains an estimate of the planar orientation of the foliation structure.

8.5.4.10.6 spacing

The spacing property (SWE::QuantityRange) contains a linear dimension representing the thickness of foliation domains. It is also used for thickness of layers of a given composition.

8.5.4.11 ShearDisplacementStructureDescription

`ShearDisplacementStructureDescription` provides extended descriptive properties of a shear displacement structure (i.e., fault or shear) defined in 8.4.3.5 by extending the abstract property block `ShearDisplacementStructureAbstractDescription`.

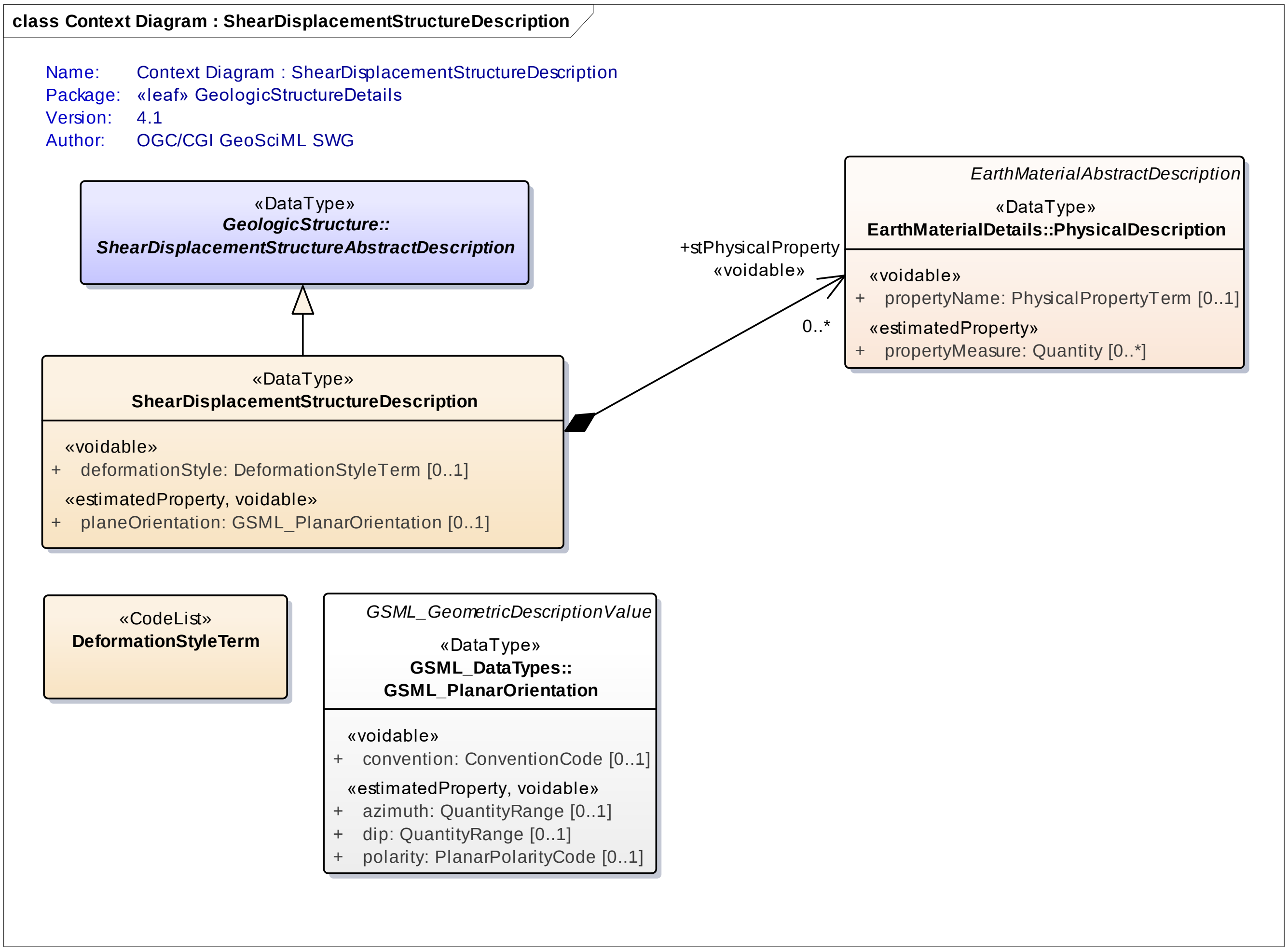


Figure 60 - ShearDisplacementStructureDescription context diagram.

8.5.4.11.1 deformationStyle

The `deformationStyle:DeformationStyleTerm` contains a term from a vocabulary to describe the style of deformation, i.e. brittle (fault, breccia), ductile (shear), brittle-ductile, unknown.

8.5.4.11.2 planeOrientation

The property `planeOrientation:GSML_PlanarOrientation` contains a description of the orientation of a structure's planar surface.

8.5.4.11.3 stPhysicalProperty

The property `stPhysicalProperty:PhysicalDescription` contains a value of generic physical properties (8.5.2.11) not addressed in this specification.

8.5.5 GeologicUnitDetails

The `GeologicUnitDetails` package provides for extended description of geologic unit features (8.4.1.3).

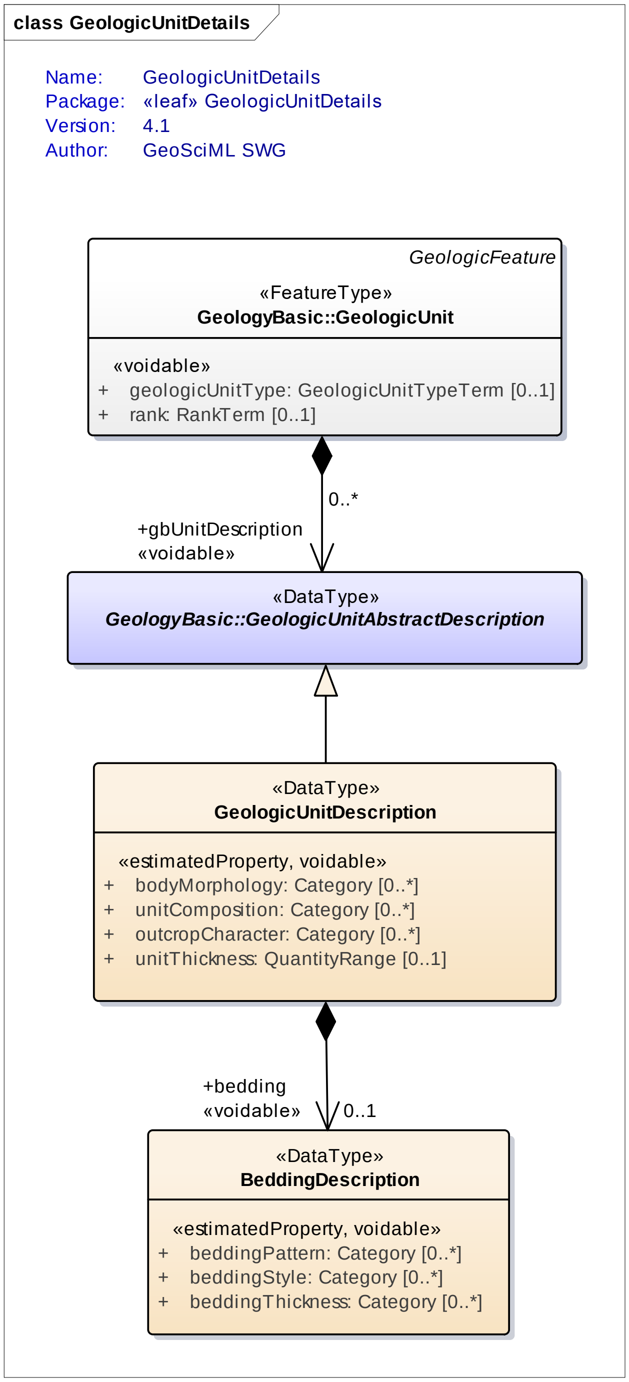


Figure 61 - GeologicUnitDetails

8.5.5.1 GeologicUnitDescription

`GeologicUnitDescription` provides for extended description of the characteristics of a geologic unit (8.4.1.3).

8.5.5.1.1 bodyMorphology

The `bodyMorphology` property (`SWE::Category`) provides a term from a controlled vocabulary describing the geometry or form of a `GeologicUnit`. Examples include: dike (dyke), cone, fan, sheet, etc. The morphology is independent of the substance (`EarthMaterial`) that composes the `GeologicUnit` or process that formed it.

8.5.5.1.2 unitComposition

The `unitComposition` property (`SWE::Category`) provides a term from a composition-based classification that requires summarising the overall character of the unit. It is not applicable at the rock material or specimen level. Examples are: alkalic, subaluminous, peraluminous, I-Type, carbonate, phosphate.

8.5.5.1.3 outcropCharacter

The property `outcropCharacter` (`SWE::Category`) provides a term that describes the nature of outcrops formed by a geologic unit. Examples are: bouldery, cliff-forming, ledge-forming, slope-forming, poorly exposed.

8.5.5.1.4 unitThickness

The property `unitThickness` (`SWE::QuantityRange`) provides a value that represents the typical thickness of the geologic unit. It is always reported as a range.

8.5.5.1.5 bedding

The `bedding:BeddingDescription` property reports a description of the bedding (see 8.5.5.2).

8.5.5.2 BeddingDescription

`BeddingDescription` provides a detailed description of the bedding characteristics of a geologic unit.

8.5.5.2.1 beddingPattern

The property `beddingPattern` (`SWE::Category`) provides a term from a controlled vocabulary specifying patterns of bedding thickness or relationships between bedding packages. (e.g., thinning upward, thickening upward).

8.5.5.2.2 beddingStyle

The property `beddingStyle` (`SWE::Category`) provides a term from a controlled vocabulary specifying the style of bedding in a stratified geologic unit (e.g. lenticular, irregular, planar, vague, and massive).

8.5.5.2.3 *beddingThickness*

The property `beddingThickness` (`SWE::Category`) provides a term from a controlled vocabulary characterizing the thickness of bedding in the unit.

8.5.6 GeoSciML Extension vocabularies

Vocabularies used in GeoSciML Extension are listed in Table 5 - GeoSciML Extension vocabularies.

Table 5 - GeoSciML Extension vocabularies.

Vocabulary	Description
GeologicRelationshipTerm	Refers to a vocabulary of terms describing a relationships between geologic features or objects.
RelationRoleTerm	Refers to a vocabulary of terms describing roles played by geologic features or objects in a geologic relationship.
AlterationTypeTerm	Refers to a vocabulary of terms describing the dominant alteration mineralogy or alteration type, in common usage. Examples include: argillic, phyllic, potassic, propylitic, calc-silicate, skarn, deuteric, greisen, serpentinisation, weathering, etc.
ConstituentPartRoleTerm	Refers to a vocabulary of terms describing the role played by a constituent part of a compound material (e.g., matrix, phenocryst).
FabricTypeTerm	Refers to a vocabulary of terms describing the type of fabric present.
MineralNameTerm	Refers to a vocabulary of mineral names.
ParticleTypeTerm	Refers to a vocabulary of terms describing the type of particle in the compound earth material (e.g., bioclast, phenocryst, pyroclast).
PhysicalPropertyTerm	Refers to a vocabulary of physical property types (e.g., density, porosity, magnetic susceptibility, magnetic remanence, conductivity, etc.).
DeformationStyleTerm	A controlled vocabulary of terms describing the style of deformation (e.g., brittle, ductile).
LineationTypeTerm	Refers to a vocabulary of terms describing the type of lineation. Examples include: flow lines, scratches, striae, slickenlines, linear arrangements of elongate components in sediments, elongate minerals, crinkles, and lines of intersection between penetrative planar structures.
MovementSenseTerm	Refers to a vocabulary of terms describing the sense of movement on a shear displacement structure.

MovementTypeTerm	Refers to a vocabulary of terms describing the type of movement (e.g., dip-slip, strike-slip).
NonDirectionalStructureTypeTerm	Refers to a vocabulary of terms describing types of non-directional structures (e.g., miarolitic cavity, flame structure, load cast, shatter cone, trace fossil, fossil mold, etc.).

8.6 GeoSciML GeologicTime Requirements Class (Normative)

Requirements Class	
/req/gsml4-geologictime	
Target type	Encoding
Dependency	ISO 19108 Temporal Schema
Dependency	SWE Common 2.0 08-094r1 Clause 7
Dependency	ISO-19156 Observations and Measurements (Topic 20)
Requirement	**/req/gsml4-timescale/start** The start TimeOrdinalEraBoundary SHALL refer to the oldest boundary

The Geologic Time package, developed by Simon Cox (CSIRO) and Steve Richard (Arizona Geological Survey) [1], contains elements used to describe the classification of geologic time: time periods, time boundaries, and the relationships between them as defined by the IUGS International Commission on Stratigraphy (ICS - http://www.stratigraphy.org/).

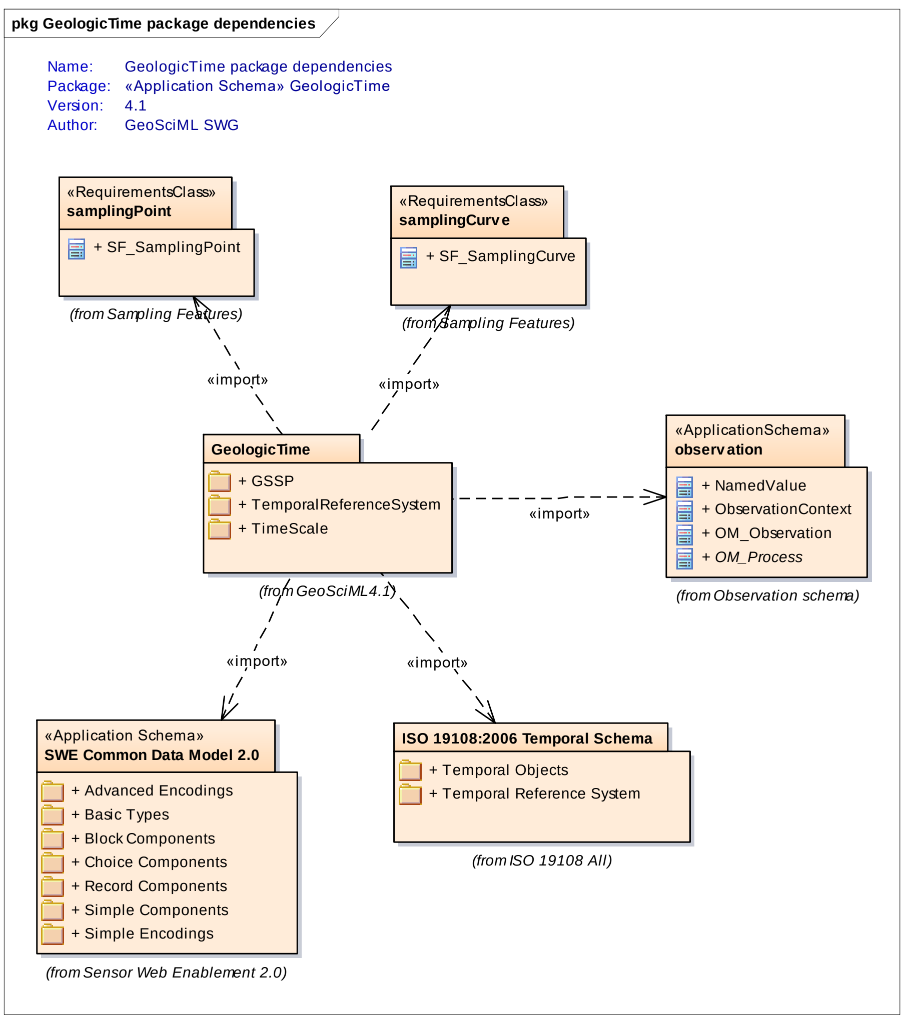


Figure 62 - GeologicTime dependencies.

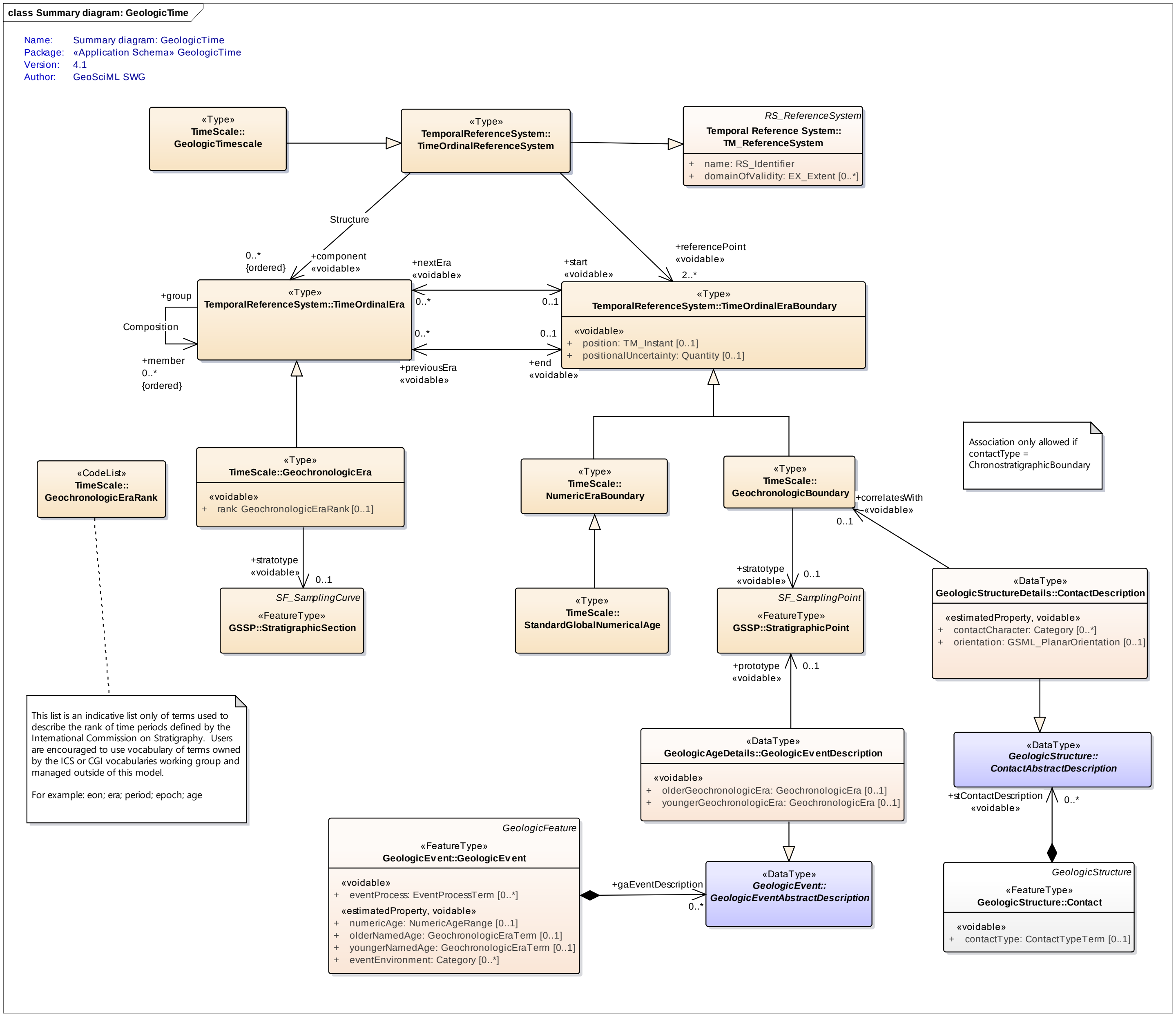


Figure 63 - Geologic Time summary diagram.

8.6.1 Global Boundary Stratotype Sections and Points (GSSP)

The GSSP model describes "Global Boundary Stratotype Sections and Points" as defined by the IUGS International Commission on Stratigraphy.

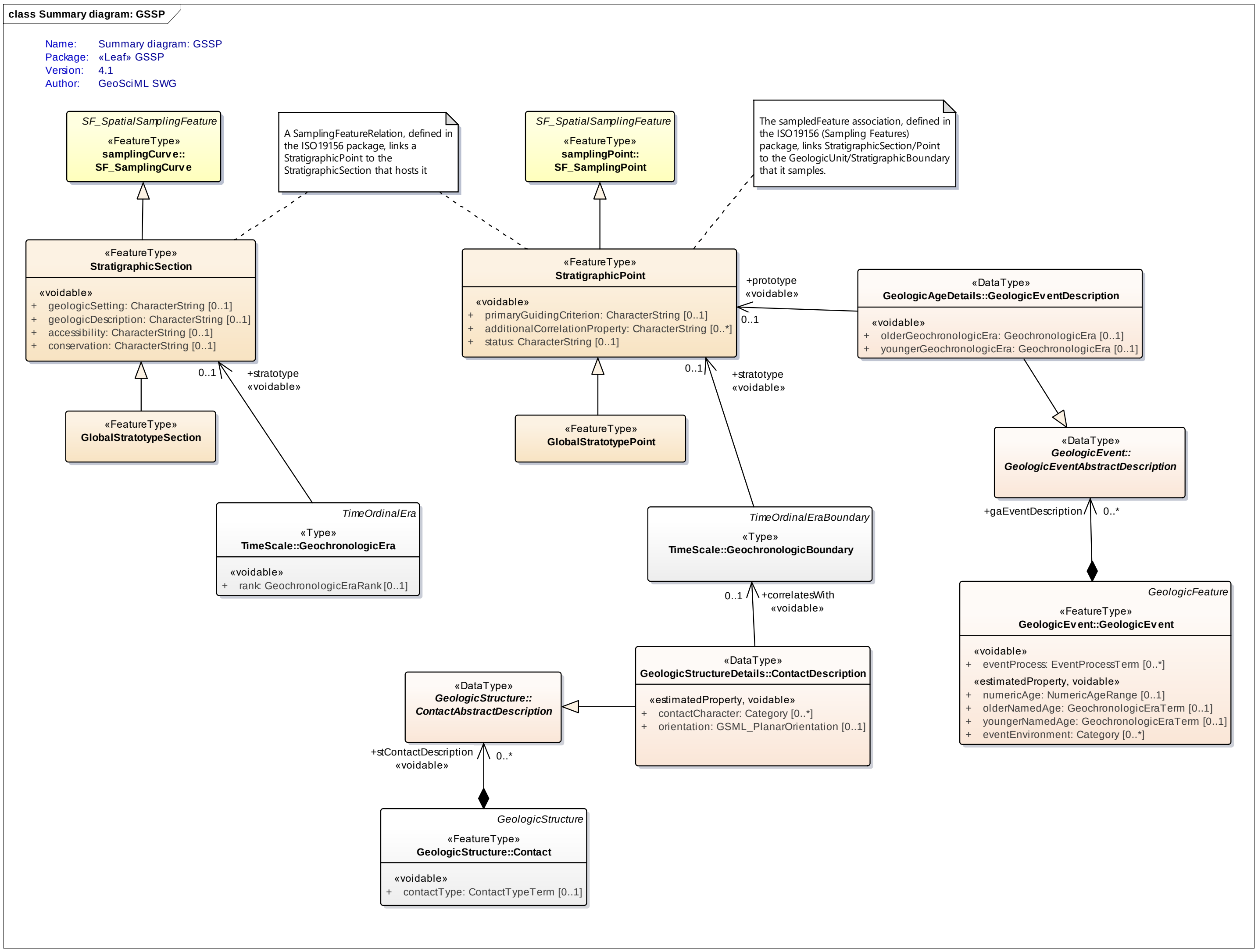


Figure 64 - Global Boundary Stratotype Sections and Points.

8.6.1.1 StratigraphicPoint

A point in the stratigraphic record used to define a geochronologic boundary or point in geologic time.

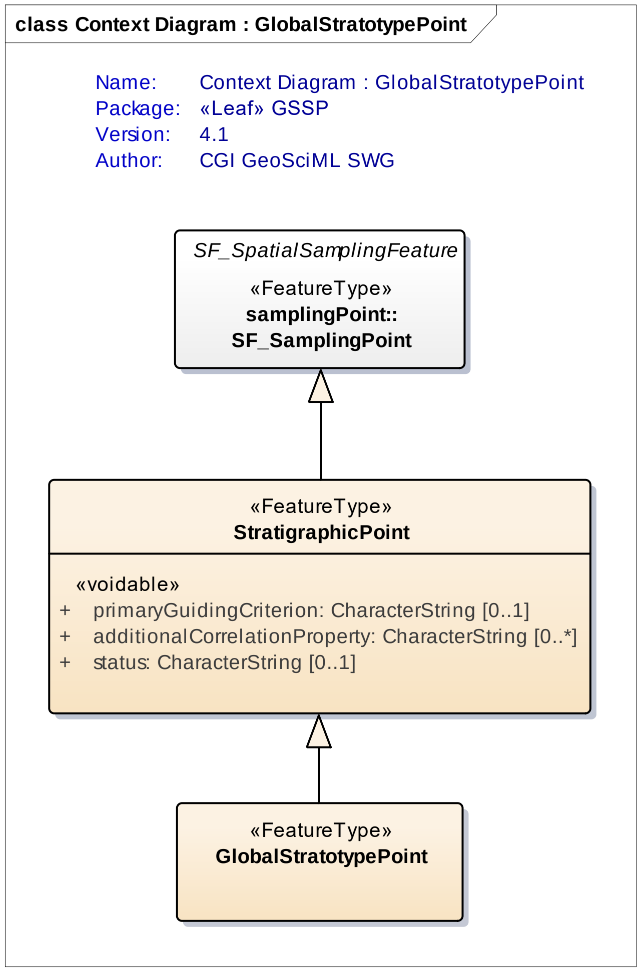


Figure 65 - Stratigraphic points context diagram

8.6.1.1.1 primaryGuidingCriterion

The property `primaryGuidingCriterion:Primitive::CharacterString` contains a description of the primary criterion used to establish the stratigraphic point.

8.6.1.1.2 additionalCorrelationProperty

The property `additionnalCorrelationProperty:Primitive::CharacterString` contains any additional criteria used to establish the stratigraphic point.

8.6.1.1.3 status

The property `status:Primitive::CharacterString` contains a description of the status of stratigraphic point (e.g., formally accepted, etc.).

8.6.1.2 GlobalStratotypePoint

A type of stratigraphic point used to define a globally agreed point in geologic time. This class does not have any properties beyond those inherited from `StratigraphicPoint`.

8.6.1.3 StratigraphicSection

A sampled section of the stratigraphic record used to define a period in geologic time.

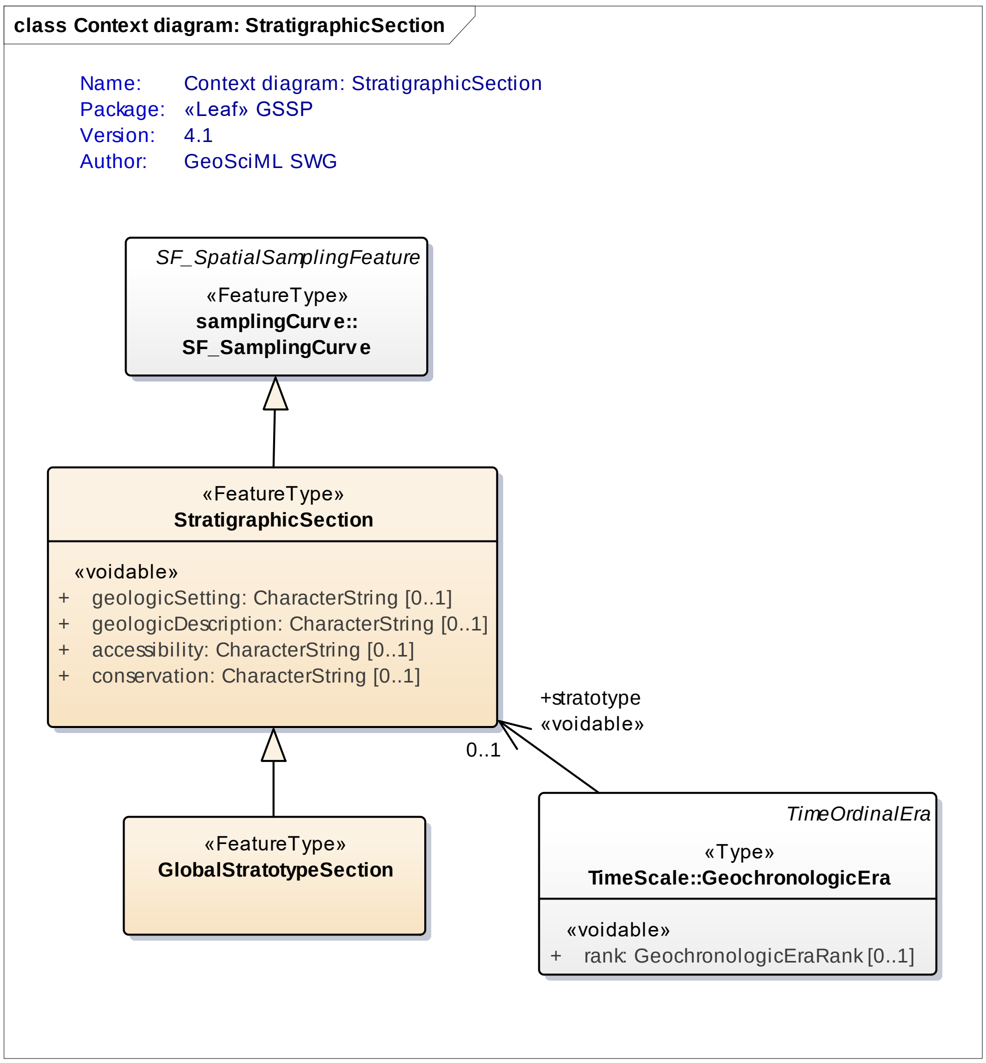


Figure 66 - Stratigraphic sections context diagram.

8.6.1.3.1 geologicSetting

The property `geologicSetting:Primitive::CharacterString` contains a description of the geologic setting of the stratigraphic section.

8.6.1.3.2 geologicDescription

The `geologicDescription:Primitive::CharacterString` contains a description of the geology of the stratigraphic section (e.g., lithology, paleontology, paleogeography, etc.).

8.6.1.3.3 accessibility

The property `accessibility:Primitive::CharacterString` contains a description of the ability to access the stratigraphic section.

8.6.1.3.4 conservation

The property `conservation:Primitive::CharacterString` contains a description of measures to conserve the stratigraphic section.

8.6.2 TemporalReferenceSystem

This package is an extension of ISO19108 Temporal Schema and describes geologic eras and the relationships between them.

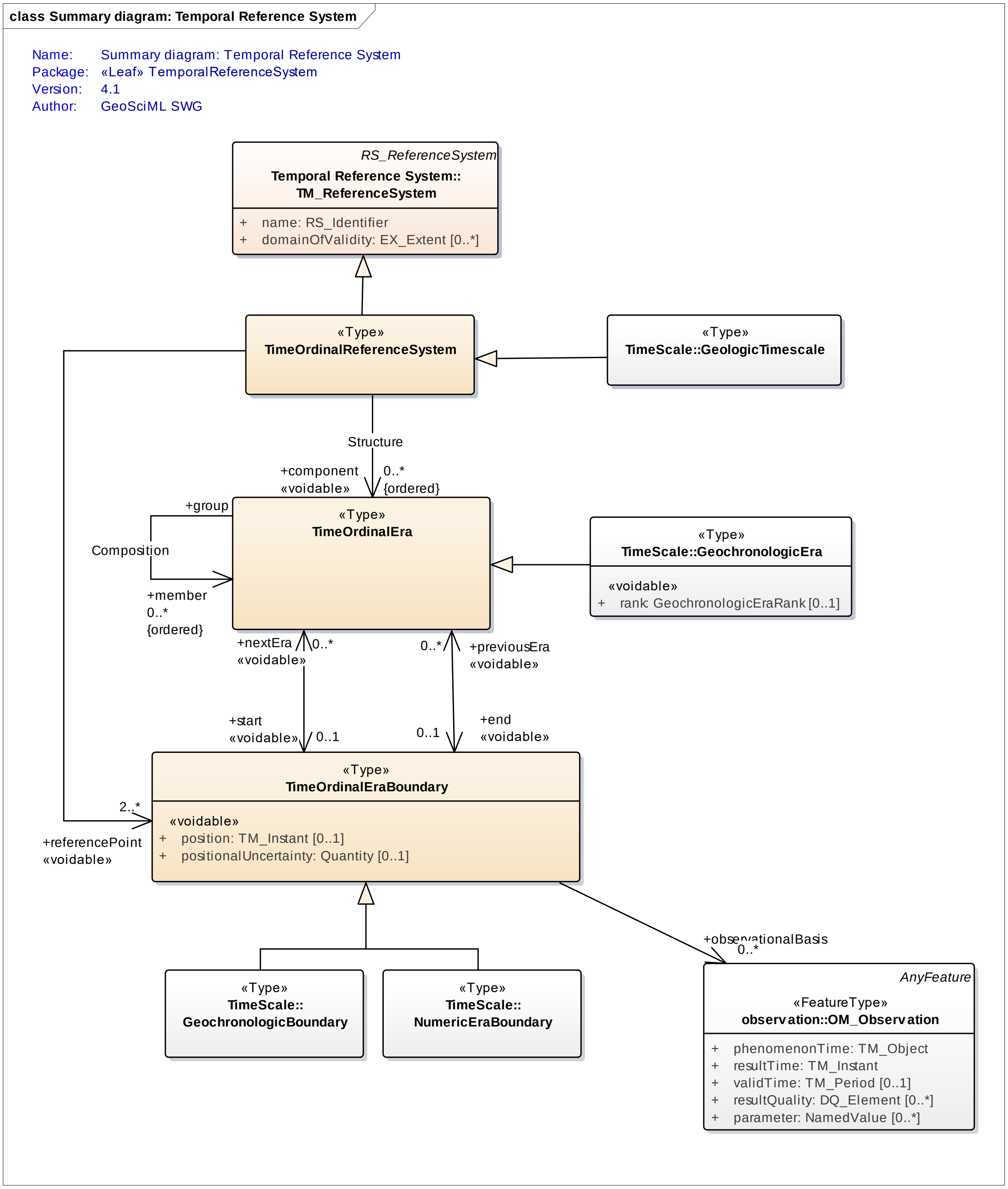


Figure 67 - Temporal Reference System summary diagram.

8.6.2.1 TimeOrdinalReferenceSystem

`TimeOrdinalReferenceSystem` is a time reference system comprised of an ordered set of time periods (time ordinal eras).

8.6.2.1.1 referencePoint

The property `referencePoint` is an association between a `TimeOrdinalReferenceSystem` and a `TimeOrdinalEraBoundary`. A `TimeOrdinalReferenceSystem` refers to two reference points defining the extent of the system.

8.6.2.1.2 component

The property `component` is an association to a `TimeOrdinalEra` that is part of the `TimeOrdinalReferenceSystem`. A `TimeOrdinalReferenceSystem` is composed of a collection of TimeOrdinalEras.

8.6.2.2 TimeOrdinalEra

`TimeOrdinalEra` is a period of time between two time boundaries. The association of an era with a stratotype is optional. In the GSSP approach recommended by ICS for the Global Geologic Timescale, Unit Stratotypes are not used. Rather, the association of an era with geologic units and sections is indirect, via the association of an era with boundaries, which are in turn tied to stratotype points, which occur within host stratotype sections. `TimeOrdinalEra` can be composed of other eras and organized into an arbitrarily nested tree.

8.6.2.2.1 member

The property `member` is an association between a `TimeOrdinalEra` and another `TimeOrdinalEra` which is hierarchically below. The referred TimeOrdinalEras are subdivision the current `TimeOrdinalEra`. Note that nesting shall not be cyclic. A `TimeOrdinalEra` can't be a member of itself or any intermediate member (we can consider that member is a transitive property). This is not a model issue but a data coherence issue.

8.6.2.2.2 group

The `group` property is an association to a (single) parent `TimeOrdinalEra`. The group associations shall not produce a cyclic graph. A `TimeOrdinalEra` group shall point to its immediate parent `TimeOrdinalEra`.

By convention, the "`start`" of the `TimeOrdinalEra` is the oldest boundary because it is when the era "started" to exist in time. The "`end`" is therefore the youngest boundary.

8.6.2.2.3 start

The `start` property is an association to a `TimeOrdinalEraBoundary` that defines the start (the oldest) boundary of the era.

/req/gsml4-timescale/start	The start `TimeOrdinalEraBoundary` SHALL refer to the oldest boundary

8.6.2.2.4 end

The `end` property is an association to a `TimeOrdinalEraBoundary` that defines the end (the youngest) boundary of the era.

8.6.2.3 TimeOrdinalEraBoundary

A `TimeOrdinalEraBoundary` is a point in Earth's history which bounds a `TimeOrdinalEra`.

8.6.2.3.1 position

The `position:TM_Instant` property describes a point in time corresponding to the era boundary.

8.6.2.3.2 positionalUncertainty

The property `positionalUncertainty` (`SWE::Quantity`) contains a measure of the uncertainty in the estimate of the point in time of the era boundary.

8.6.2.3.3 previousEra

The property `previousEra` is an association between a `TimeOrdinalEraBoundary` and a `TimeOrdinalEra` to reference the preceding (oldest) era.

8.6.2.3.4 nextEra

The property `nextEra` is an association between a `TimeOrdinalEraBoundary` and a `TimeOrdinalEra` to reference the succeeding era.

8.6.2.3.5 observationalBasis

The property `observationalBasis` is be an association between a `TimeOrdinalEraBoundary` and an `OM::OM_Observation` in support of the existence of the boundary defined by geochronology, paleontology, or other evidence.

8.6.3 Timescale

The `Timescale` package describes geologic time periods (geochronologic eras) and the boundaries between them.

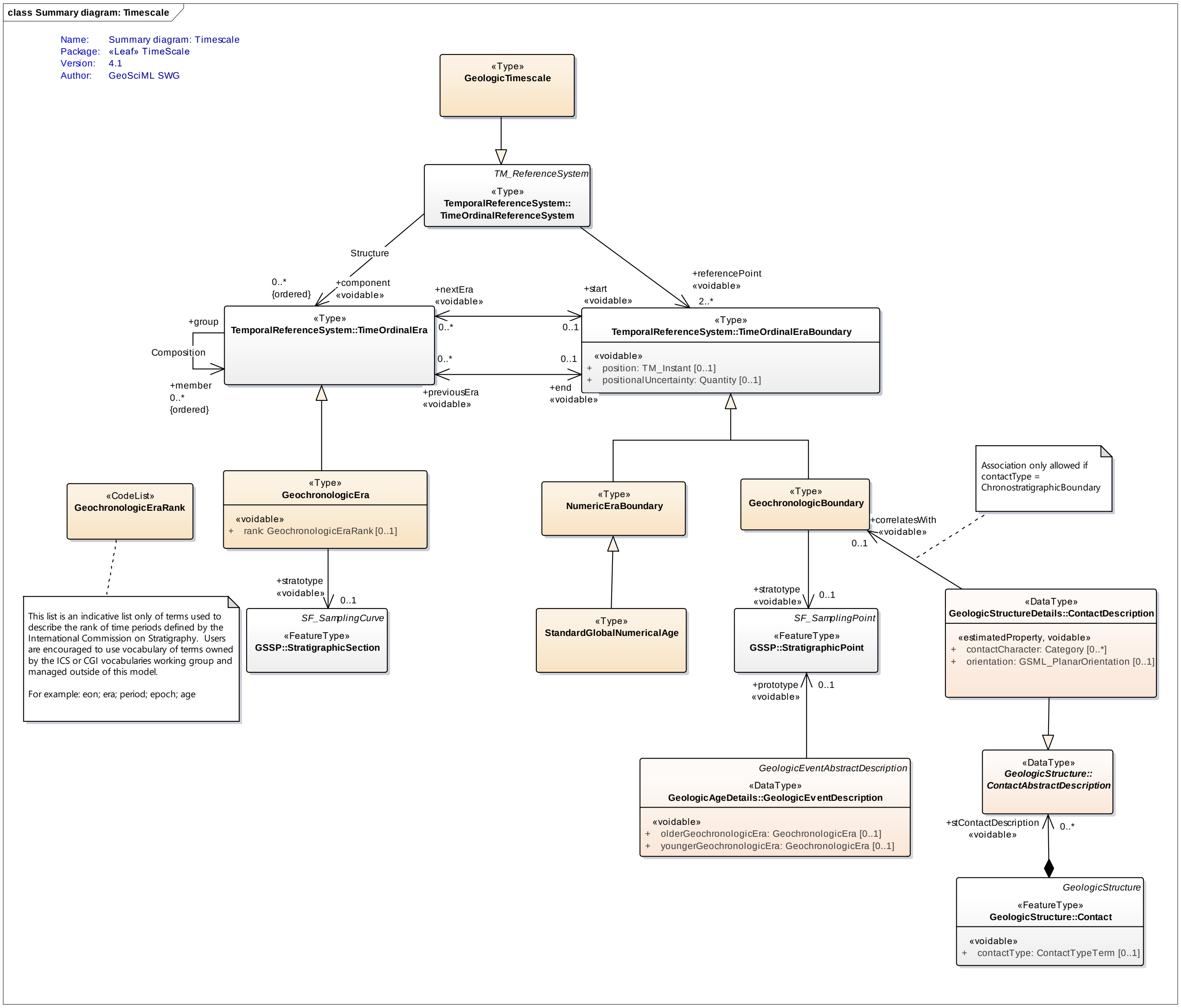


Figure 68 - Time scale summary diagram.

8.6.3.1 GeologicTimeScale

The classic "Geologic Timescale" (http://www.stratigraphy.org/index.php/ics-chart-timescale) comprising an ordered, hierarchical set of named "eras" is an example of an Ordinal Temporal Reference System. It may be calibrated with reference to a numeric Temporal Coordinate System, but is, in principle, defined independently.

8.6.3.2 GeochronologicEra

A `GeochronologicEra` is a period of time between two `GeochronologicBoundaries`. The association of a `GeochronologicEra` with a stratotype is optional. In the GSSP approach recommended by ICS for the Global Geologic Timescale, Unit Stratotypes are not used. Rather, the association of an era with geologic units and sections is indirect, via the association of an era with boundaries, which are in turn tied to stratotype points, which occur within host stratotype sections.

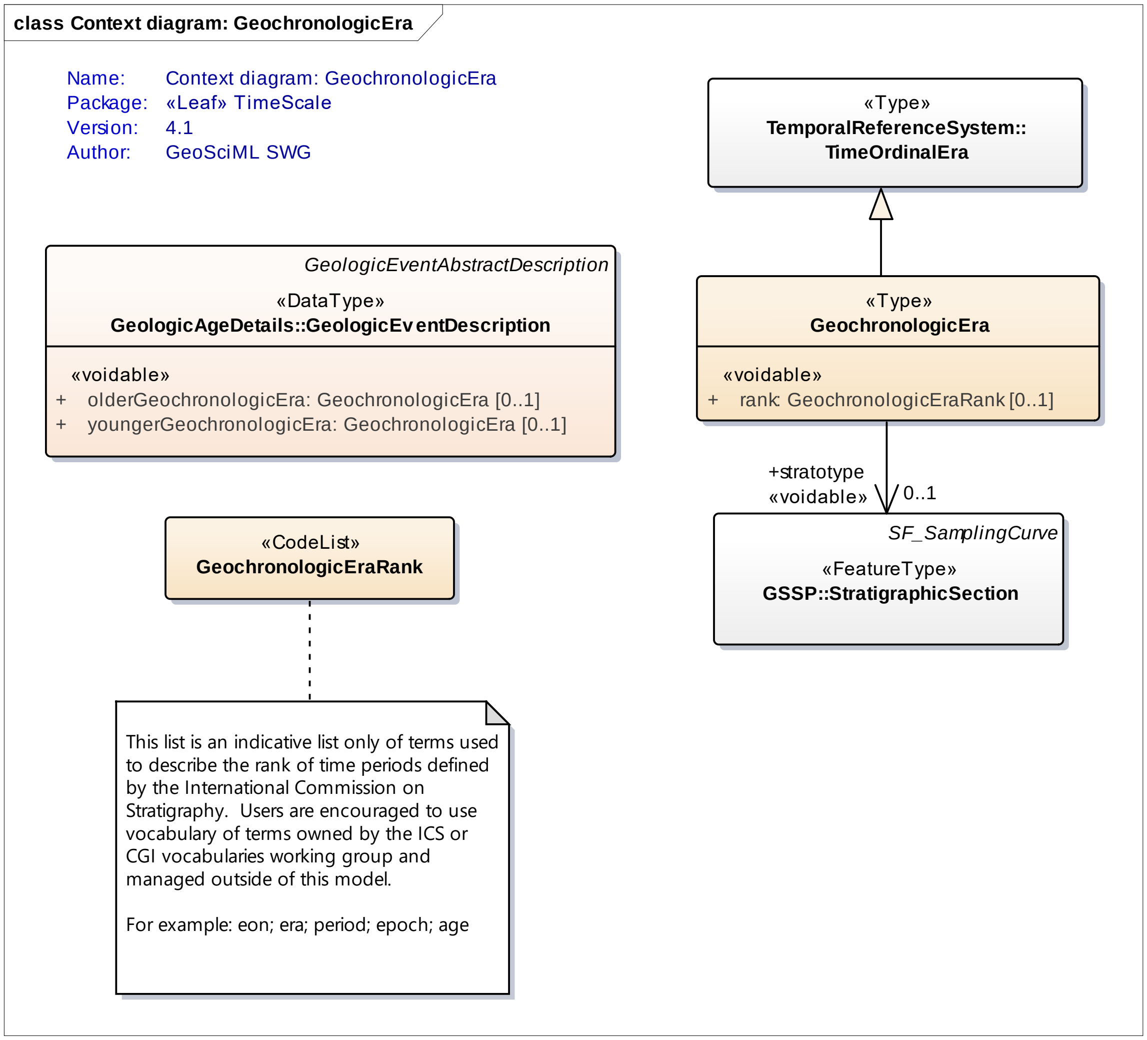


Figure 69 - GeochronologicEra context diagram.

8.6.3.2.1 rank

The property `rank:GeochronologicEraRank` contains a term from a vocabulary describing the rank of the time period (e.g., eon, era, period, stage).

8.6.3.2.2 stratotype

The property `stratotype` is an association between a `GeochronologicEra` and `StratigraphicSection` that describes a type section that names the physical location or outcrop of a particular reference exposure of a stratigraphic sequence or stratigraphic boundary. A unit stratotype is the agreed reference point for a particular stratigraphic unit and a boundary stratotype is the reference for a particular boundary between strata (Wikipedia).

8.6.3.3 GeochronologicBoundary

A `GeochronologicBoundary` is a boundary between two geochronologic time periods.

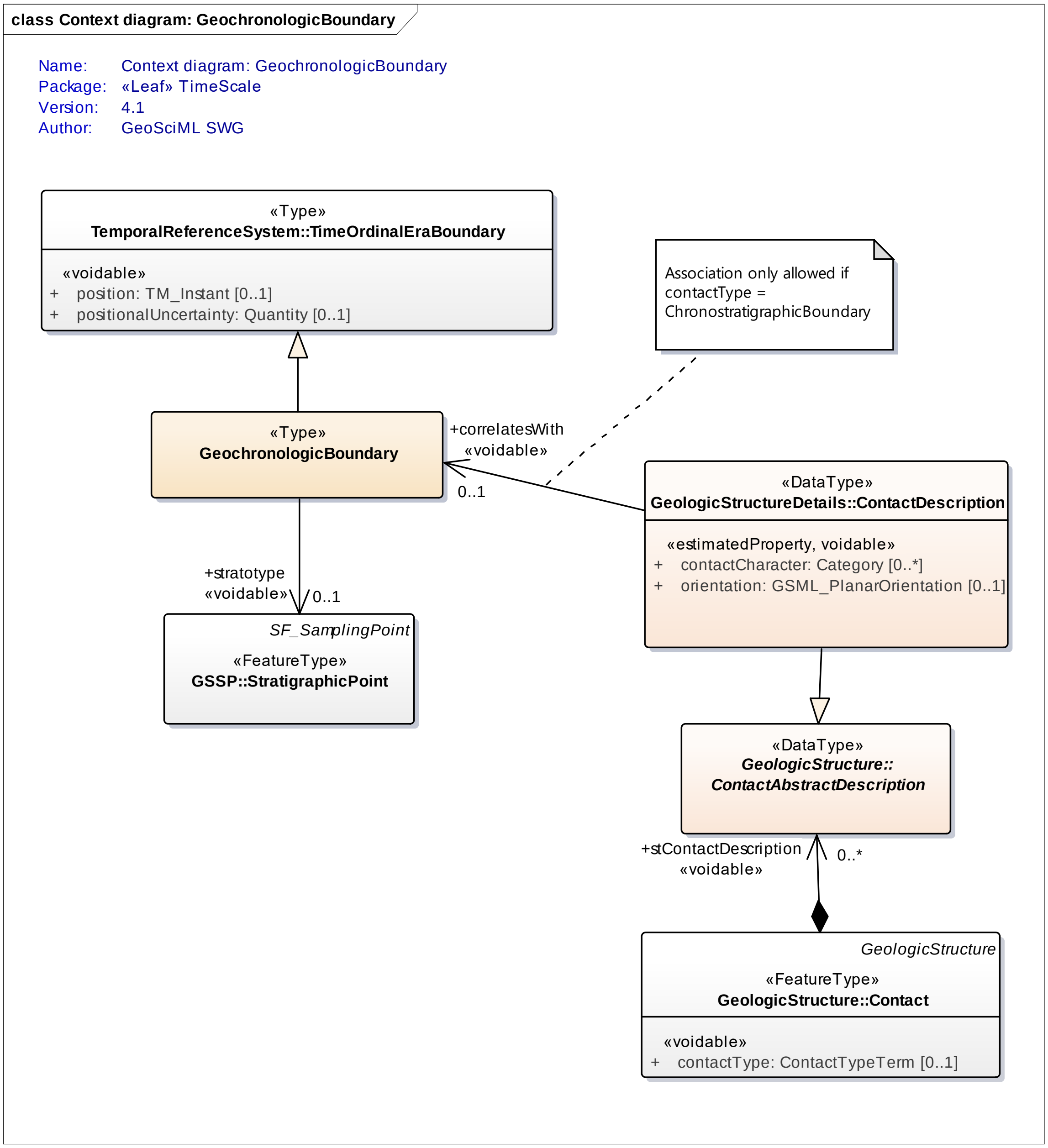


Figure 70 - GeochronologicBoundary context diagram.

8.6.3.3.1 stratotype

The property `stratotype` is an association between a `GeochronologicBoundary` and a `StratigraphicPoint` that are associated with the boundary. A `GeochronologicBoundary` can be associated with more than one `StratigraphicPoints`, but only one may have GSSP ratified status. The others are proposed equivalents.

Example:

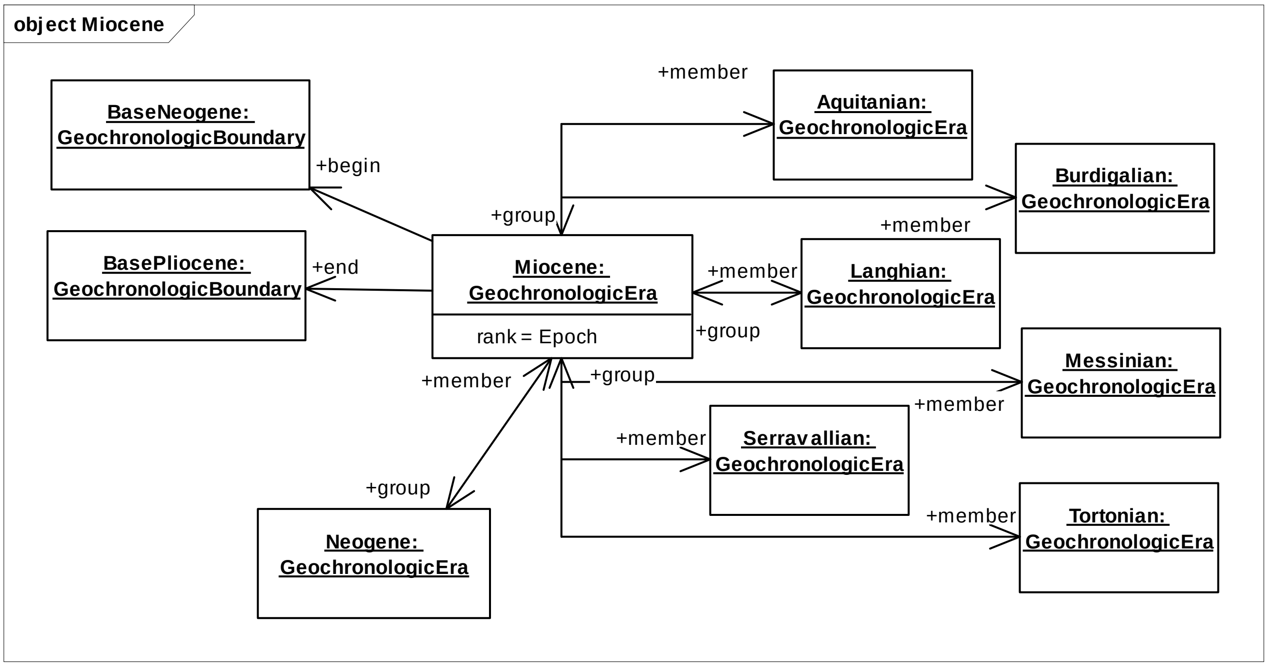


Figure 71 - Partial encoding of Miocene instance diagram.

8.6.3.4 NumericEraBoundary

`NumericEraBoundary` is used for pre-Ediacaran and Pleistocene / Holocene boundaries in the standard timescale where boundaries are not defined by a material reference but as numerical values.

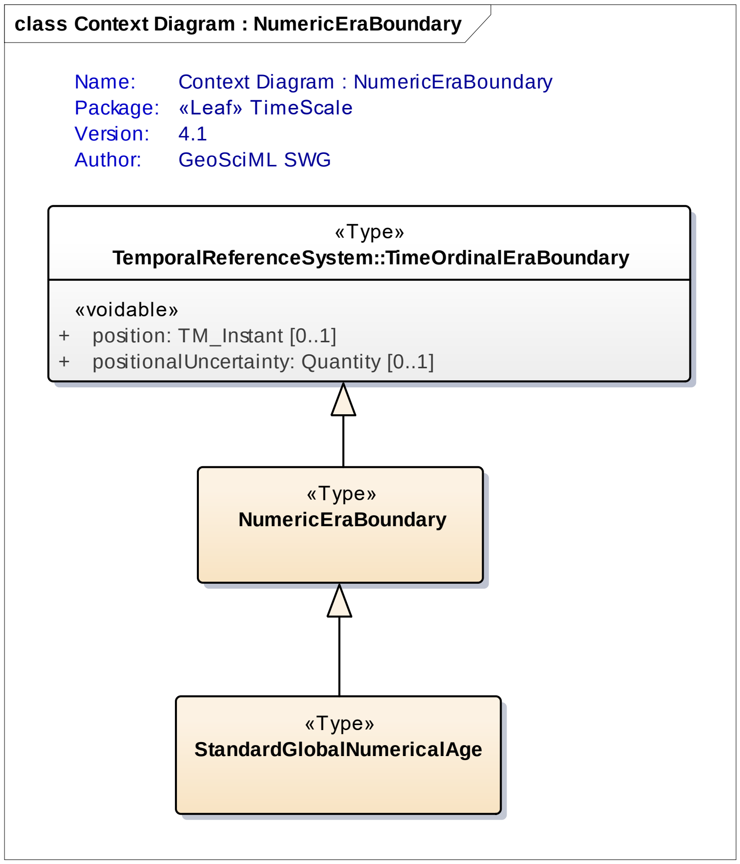


Figure 72 - NumericEraBoundary context diagram.

8.6.3.5 StandardGlobalNumericalAge

A standard numeric age point (a numeric analogue to a 'golden spike') is applicable to the formal subdivision of the Precambrian, and perhaps the Pleistocene/Holocene boundary ([23]; http://www.stratigraphy.org/index.php/ics-chart-timescale). The boundary is not defined from a physical stratotype, although it can be influence by some, but placed at a convenient numerical value.

8.6.4 **GeoSciML GeologicTime vocabularies**

The GeologicTime package has only one vocabulary (Table 6).

Table 6 - Geologic time vocabulary.

Vocabulary	Description
GeochronologicEraRank	This list is an indicative list only of terms used to describe the rank of time periods defined by the International Commission on Stratigraphy. Users are encouraged to use vocabulary of terms owned by the ICS or CGI vocabularies working group and managed outside of this model. For example: • eon • era • period • epoch • age

8.7 GeoSciML Borehole Requirements Class (Normative)

Requirements Class	
/req/gsml4-borehole	
Target type	Encoding
Dependency	/req/gsml4-core
Dependency	ISO 19103 Conceptual Model Language
Dependency	ISO 19107 Spatial Schema
Dependency	ISO-19156 Observations and Measurements (OGC Topic 20)
Dependency	SWE Common 2.0 08-094r1 Clause 7
Dependency	ISO 19108 Temporal Schema
Dependency	ISO 19115-3 Citation
Requirement	**/req/gsml4-borehole/value-intervalBegin** The value of intervalBegin SHALL be less or equal to the value of intervalEnd.
Requirement	**/req/gsml4-borehole/drill-interval-1D** Interval SHALL be encoded with GM_LineString with two 1D points.
Requirement	**/req/gsml4-borehole/drill-interval-1D-CRS** Coordinate Reference System shall be a reference to the borehole geometry.
Requirement	**/req/gsml4-borehole/value-mappedIntervalBegin** The value of mappedIntervalBegin SHALL be less or equal to the value of mappedIntervalEnd.
Requirement	**/req/gsml4-borehole/interval-1D** Interval SHALL be encoded with GM_LineString with two 1D points.
Requirement	**/req/gsml4-borehole/interval-1D-CRS**

	Coordinate Reference System of interval geometries SHALL use the borehole geometry.
Requirement	**/req/gsml4-borehole/borehole-position-null** If no GM_Point is available, an OGC nil value SHALL be used.
Recommendation	**/req/gsml4-borehole/borehole-3d** Implementers delivering 3-D origin locations SHOULD provide an elevation.
Requirement	**/req/gsml4-borehole/borehole-elevation-dim** Origin elevation SHALL be a geometry with a dimension of 1.
Requirement	**/req/gsml4-borehole/borehole-elevation-CRS** Origin elevation srsName identifier SHALL be a vertical CRS having a EPSG in the range 5600-5799

The GeoSciML `Borehole` package contains an information model for boreholes and related artefacts. This is primarily through re-use of standard components from the Observations and Measurements (ISO19156).

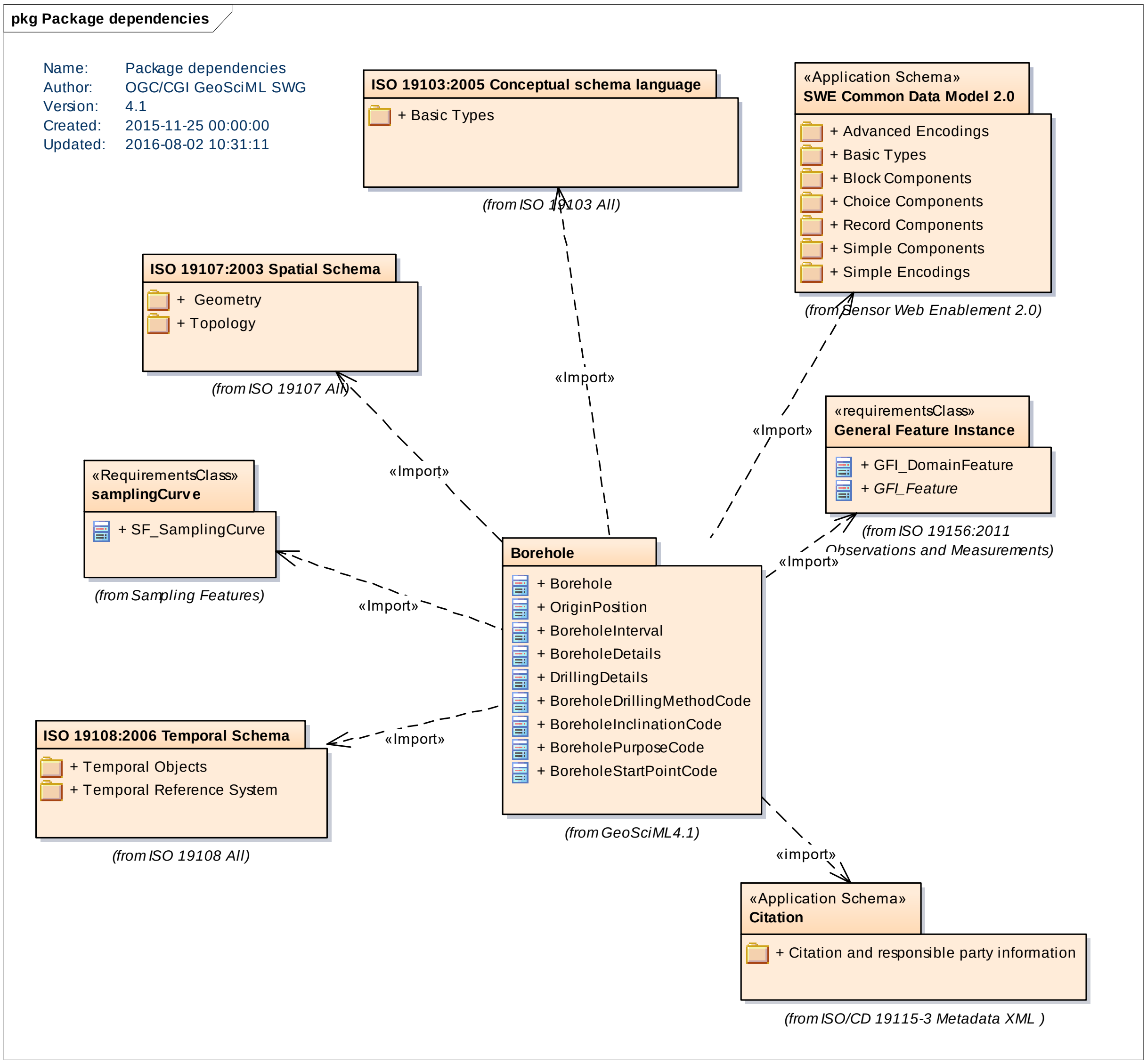


Figure 73 - Borehole dependency diagram.

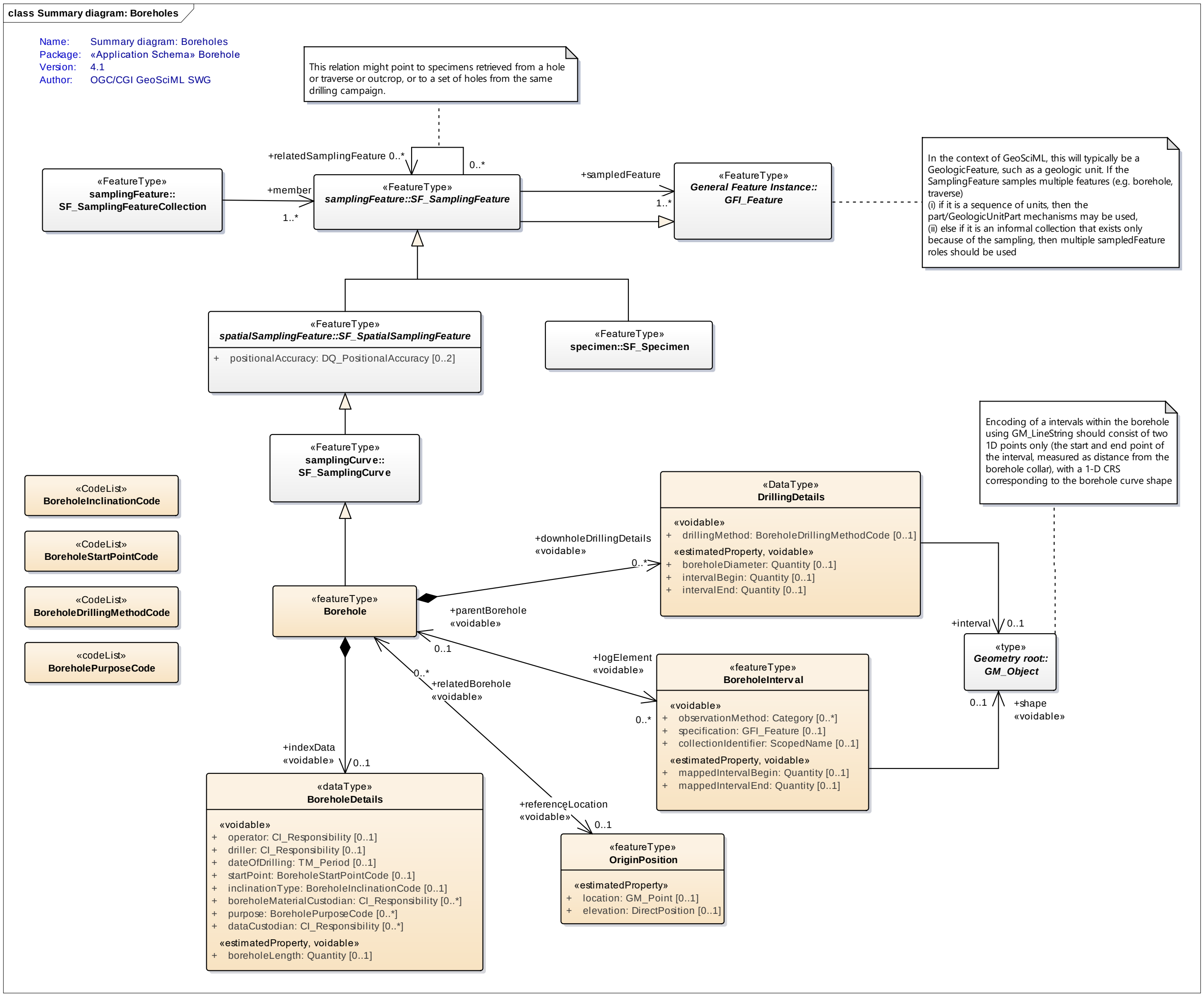


Figure 74 - Borehole summary diagram.

8.7.1 Borehole

This requirements class describes `Borehole` and `BoreholeInterval` and related data types. This package describes a borehole as a means to sample geologic units underground and thus provide a linear map of the geology.

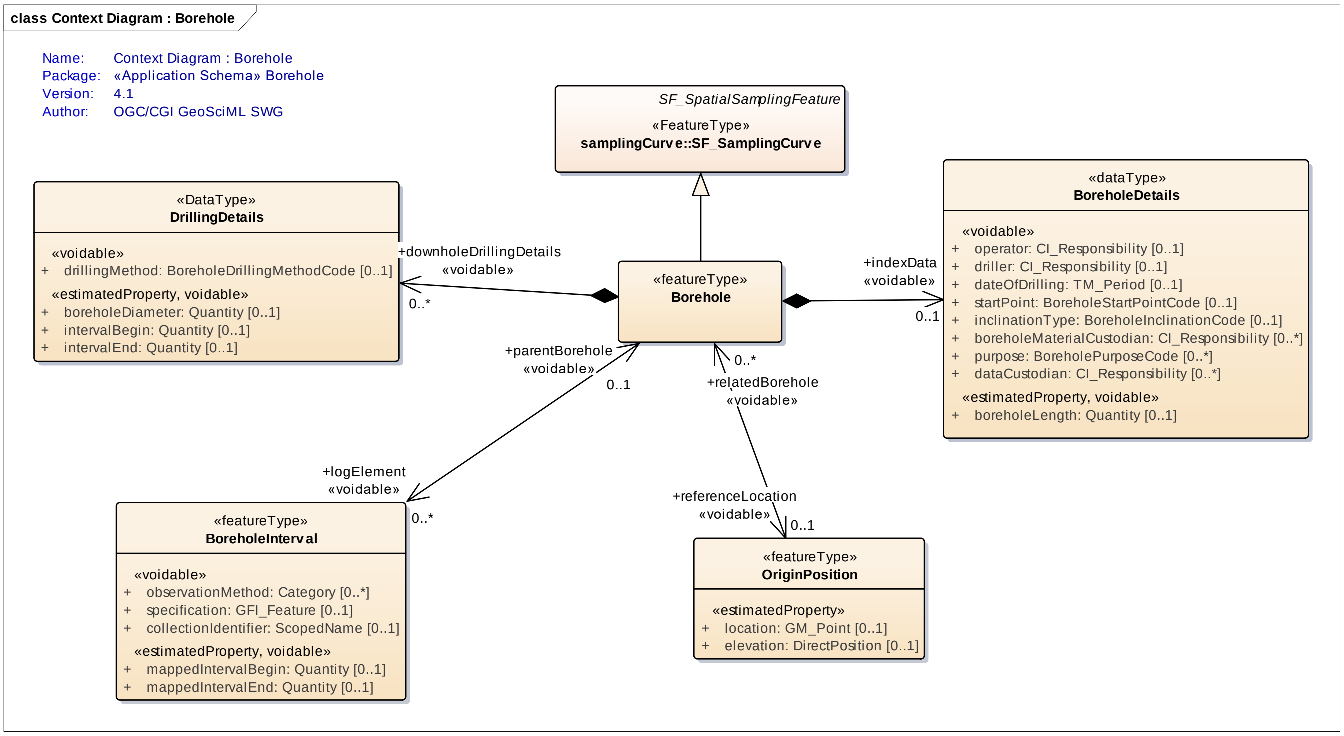


Figure 75 - Borehole context diagram.

8.7.1.1 Borehole

A `Borehole` is the generalized term for any narrow shaft drilled in the ground, either vertically, horizontally, or inclined.

8.7.1.1.1 indexData

The property `indexData:BoreholeDetails` describes metadata about a borehole, such as the operator, the custodian, dates of drilling, etc.

8.7.1.1.2 downholeDrillingDetails

The property `downholeDrillingDetails:DrillingDetails` specifies the drilling method and borehole diameter for intervals down the borehole.

8.7.1.1.3 logElement

The property `logElement` is an association between a `Borehole` and a `BoreholeInterval` instance to describe measured downhole intervals and their observed features.

8.7.1.1.4 referenceLocation

The property `referenceLocation` is an association between a `Borehole` and an `OriginPosition` corresponding to the start point of a borehole log. This may correspond to the borehole collar location (e.g., kelly bush).

8.7.1.1.5 OM:sampledFeature

`Borehole` inherits `sampledFeature` from `OM::SF_SamplingFeature`, which links the sampling feature to the real world feature it is designed to sample (19156:2011, clause 9.2.2.4). In the context of GeoSciML, this will typically be a `GeologicFeature`, such as a geologic unit. Where a `SamplingFeature` samples multiple features (e.g. borehole, traverse)

- if it is a sequence of units, then the `part:GeologicUnitPart` mechanisms may be used,
- else if it is an informal collection that exists only because of the sampling, then multiple `sampledFeature` roles should be used

8.7.1.2 DrillingDetails

`DrillingDetails` is a class that captures the description of drilling methods and hole diameters down the drilling path. Properties that apply to the `Borehole` as a whole are managed in `BoreholeDetails` (0).

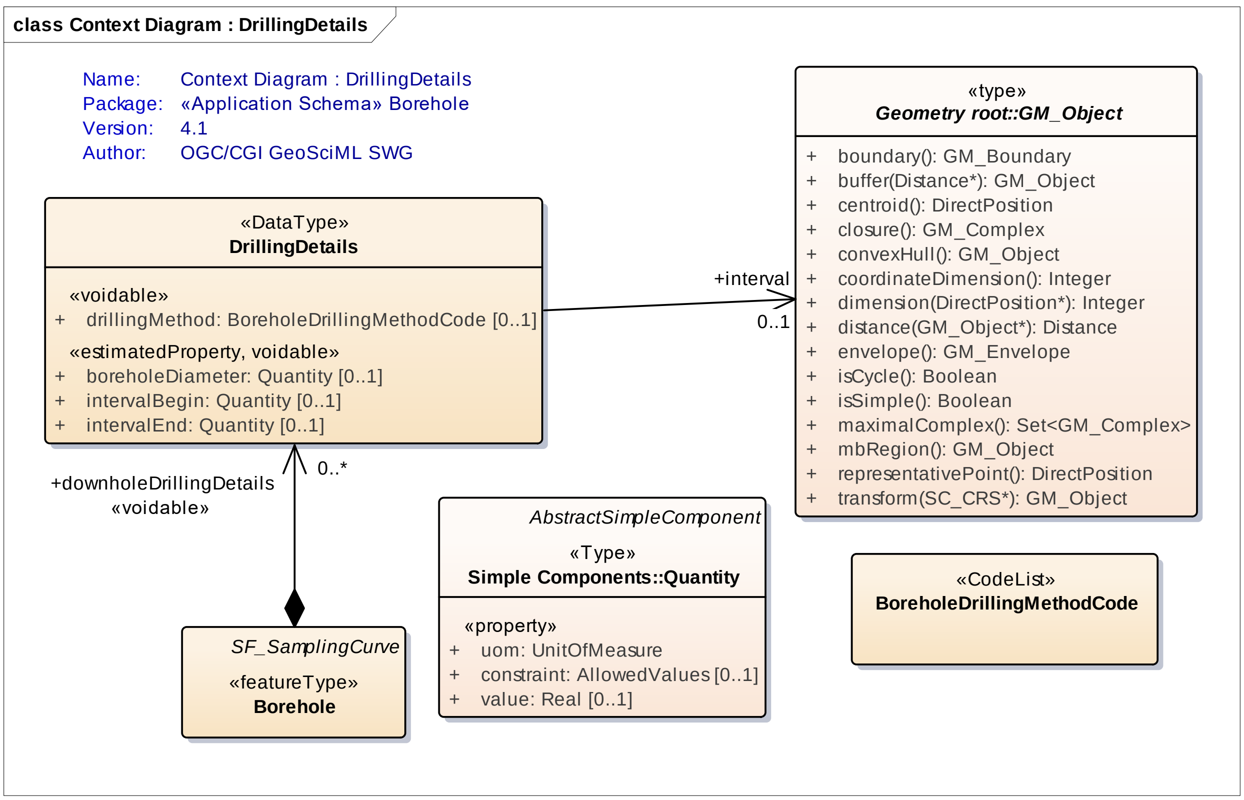


Figure 76 - Drilling details

8.7.1.2.1 drillingMethod

The `drillingMethod:BoreholeDrillingMethodCode` property contains a term from a controlled vocabulary indicating the drilling method used. Appropriate terms would include rotary air blast, auger, diamond core, air core, etc.

8.7.1.2.2 boreholeDiameter

The `boreholeDiameter` property (`SWE::Quantity`) contains a measurement (a value and a unit of measure) corresponding to the diameter of the drilled hole.

8.7.1.2.3 intervalBegin

The `intervalBegin` property (`SWE::Quantity`) contains a measurement (a value and a unit of measurement) that corresponds to the measured distance of the start of the interval along the path of the borehole. The measured value must be less than or equal to the `intervalEnd` value.

/req/gsml4-borehole/value-intervalBegin	The value of `intervalBegin` SHALL be less or equal to the value of `intervalEnd`.

8.7.1.2.4 intervalEnd

The property `intervalEnd` (`SWE::Quantity`) contains a measurement (a value and a unit of measurement) of the measured distance of the end of the interval along the path of the borehole. The measured value must be greater than or equal to the `intervalBegin` value.

8.7.1.2.5 interval

The property `interval:GM_Object` is a shape that is a 1-D interval (e.g., a "from" and "to", or "top" and "base" measurements) that is equivalent (represents the same distance) as the one represented by `intervalBegin` and `intervalEnd`. The geometry shall use a reference to the borehole geometry as its CRS.

/req/gsml4-borehole/drill-interval-1D	Interval SHALL be encoded with `GM_LineString` with two 1D points.

/req/gsml4-borehole/drill-interval-1D-CRS	Coordinate Reference System shall be a reference to the borehole geometry.

Encoding of the drilled interval using `GEO::GM_LineString` shall consist of two 1D points only (the start and end point of the interval, measured as distance from the borehole collar), with a 1-D CRS referencing the borehole shape.

8.7.1.3 BoreholeInterval

A `BoreholeInterval` is similar to a `MappedFeature` (8.4.1.2) whose shape is 1-D interval and uses the SRS of the containing borehole. The "`mappedIntervalBegin`" and "`mappedIntervalEnd`" properties are alternative to the 1D geometry to overcome problems with the delivery and ease of queryability of 1D GML shapes.

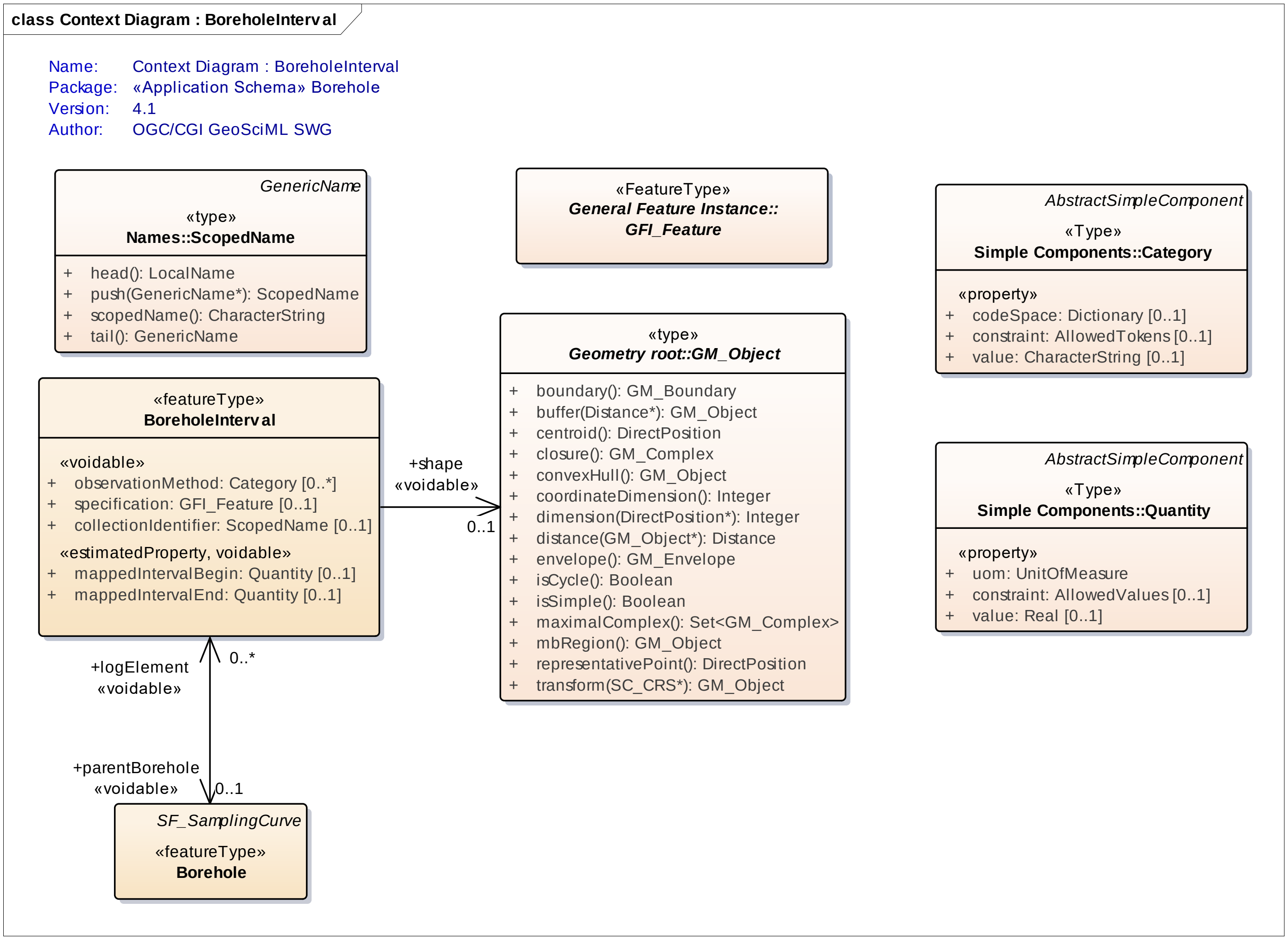


Figure 77 - Borehole interval context diagram.

8.7.1.3.1 observationMethod

The `observationMethod property (SWE::Category)` contains a term from a controlled vocabulary that describes the method used to observe the properties of the borehole.

8.7.1.3.2 specification

The `specification` property is an association between a `BoreholeInterval` and a `GFI_Feature`, a domain feature that is sampled by the interval (e.g., a `GeologicUnit`). It is semantically equivalent to O&M ISO19156 "`sampledFeature`".

8.7.1.3.3 mappedIntervalBegin

The property `mappedIntervalBegin` (`SWE::Quantity`) is a measurement (a value and a unit of measurement) corresponding to the measured distance of the start of the mapped interval along the path of the borehole. The measured value must be less than or equal to the `mappedIntervalEnd` value.

/req/gsml4-borehole/value-mappedIntervalBegin	The value of `mappedIntervalBegin` SHALL be less than or equal to the value of `mappedIntervalEnd`.

8.7.1.3.4 mappedIntervalEnd

The `mappedIntervalEnd` property (`SWE::Quantity`) is a measurement (a value and a unit of measure) corresponding to the measured distance of the end of the mapped interval along the path of the borehole. The measured value must be greater than or equal to the `mappedIntervalBegin` value.

8.7.1.3.5 collectionIdentifier

The `collectionIdentifier:ScopedName` is a string unique within a scope that identifies a collection which forms a set `BoreholeIntervals`. This allows description of multiple downhole logs for a single borehole. The name should identify a particular log observation event.

8.7.1.3.6 parentBorehole

The property `parentBorehole` is an association between a `BoreholeInterval` and a `Borehole` to which the interval belongs.

8.7.1.3.7 shape

The property `shape:GM_Object` is a 1-D interval (e.g., a "from" and "to", or "top" and "base" measurement) covering the same distance as `mappedIntervalBegin` and `mappedIntervalEnd`. The geometry shall use a reference to the borehole as the CRS of the containing borehole.

Encoding of an interval within the borehole using `GEO::GM_LineString` shall consist of two 1D points only (the start and end point of the interval, measured as distance from the borehole collar), with CRS corresponding to the borehole shape.

/req/gsml4-borehole/interval-1D	Interval SHALL be encoded with `GM_LineString` with two 1D points.

/req/gsml4-borehole/interval-1D-CRS	Coordinate Reference System of interval geometries SHALL use the borehole geometry.

Instance example for Klčovo and Lastomir Formation adapted from Túnyi [18]:

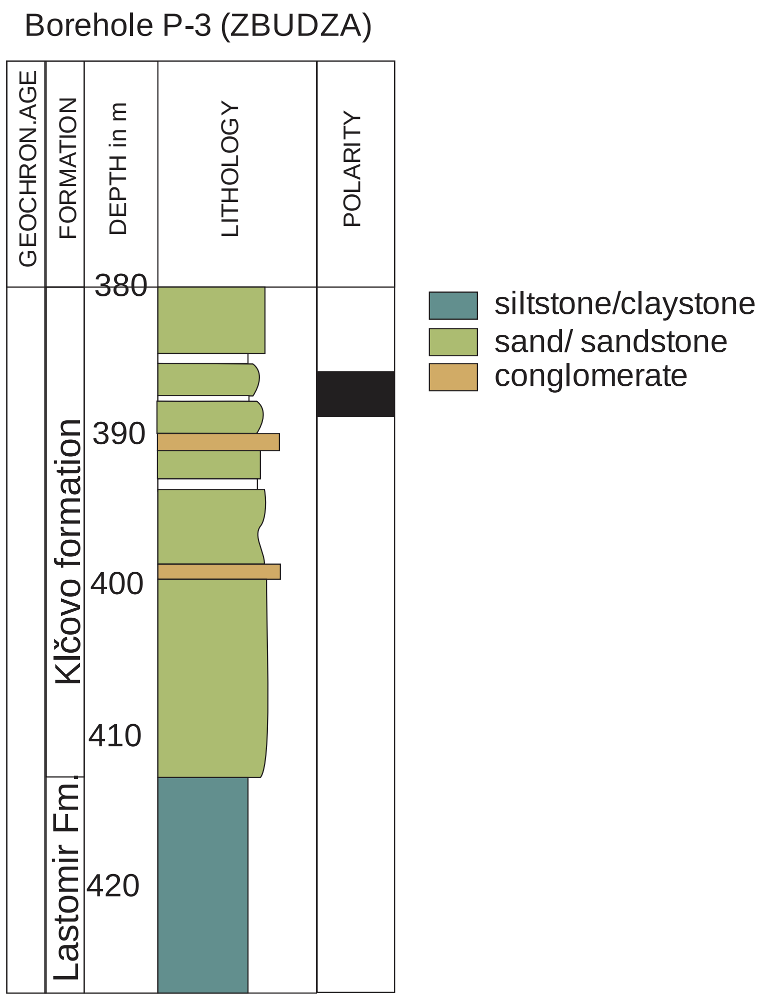


Figure 78 - Top part of Figure 2 from Túnyi [18]

Figure 79 shows an encoding of the first lithostratigraphic and magnetostratigraphic units from Figure 78 showing how the collection identifiers group `BoreholeIntervals` into two groups.

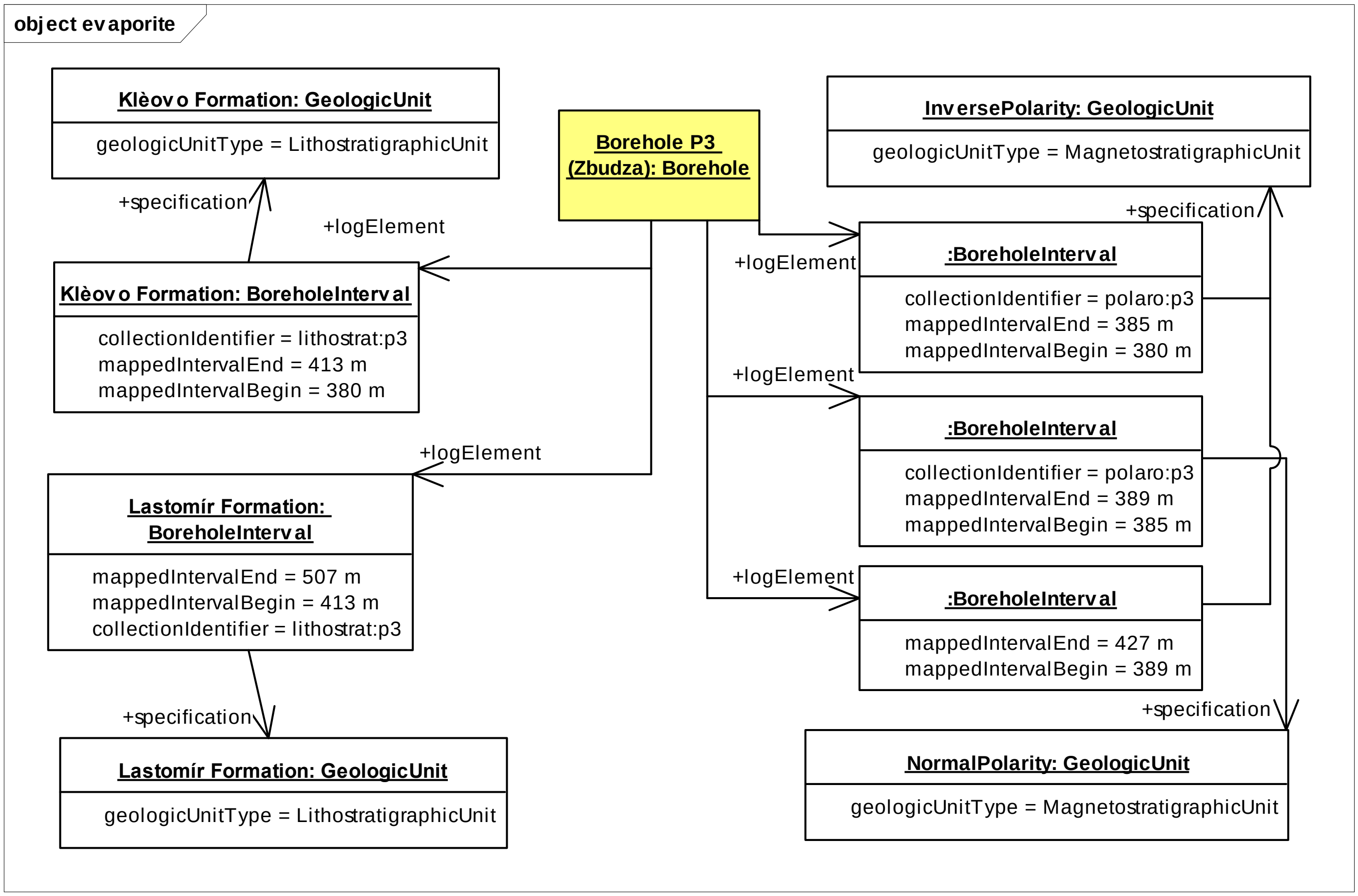


Figure 79 - Encoding of a borehole with two distinct logs (collectionIdentifier).

8.7.1.4 BoreholeDetails

`BoreholeDetails` describes borehole-specific index data, often termed "header information". It contains metadata about the parties involved in the drilling, the storage of drilled material and other information relevant to the borehole as a whole. Properties that may vary along the borehole path are managed in `DrillingDetails` (8.7.1.2).

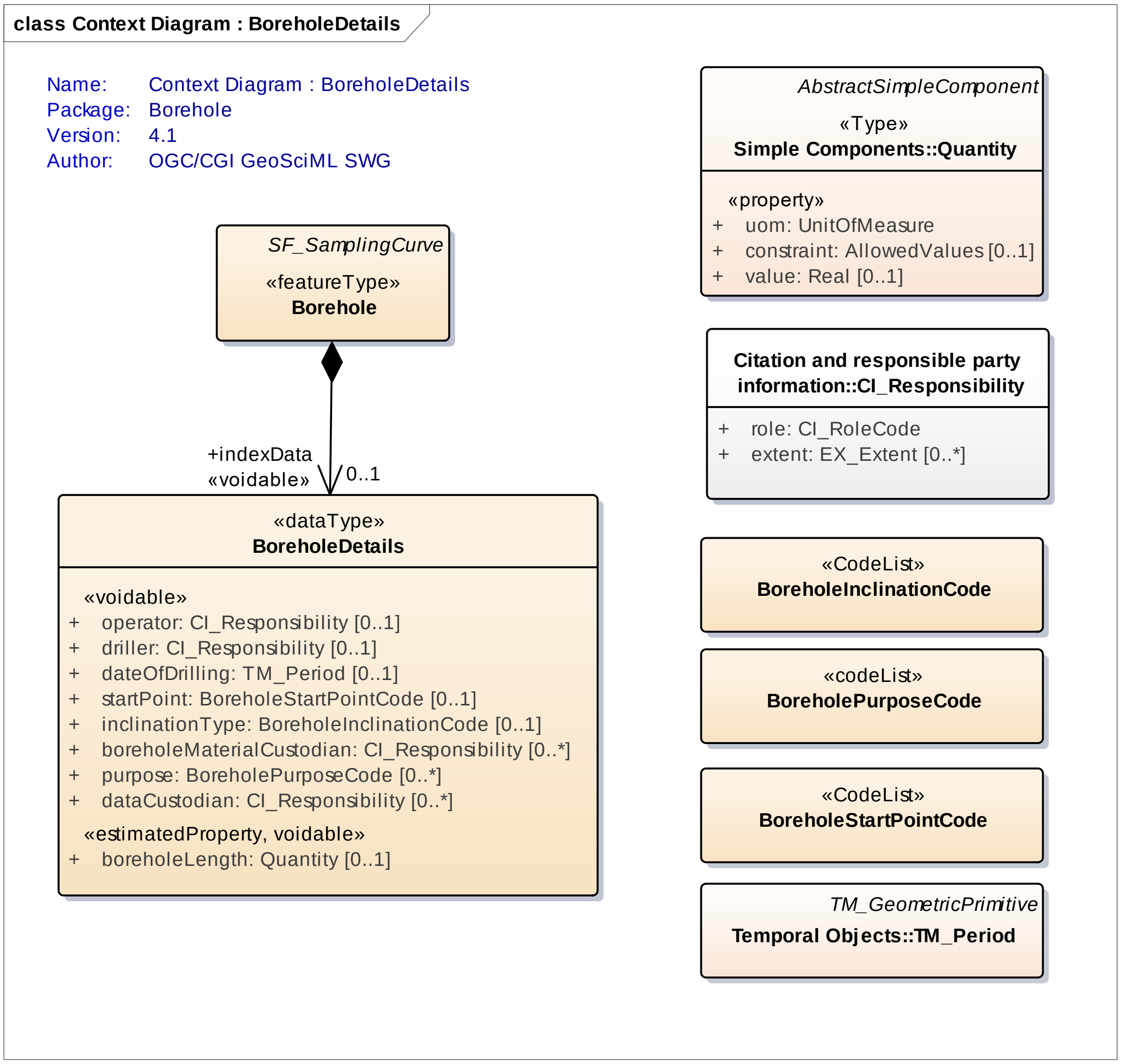


Figure 80 - Borehole details context diagram.

8.7.1.4.1 operator

The `operator` property is an association between a `BoreholeDetails` and a `CIT:CI_ResponsibleParty` describing the organisation responsible for commissioning the borehole (as opposed to actually drilling the borehole).

8.7.1.4.2 driller

The `driller` property is an association between a `BoreholeDetails` and a `CIT:CI_ResponsibleParty` describing of the organisation responsible for drilling the borehole (as opposed to commissioning the borehole).

8.7.1.4.3 dateOfDrilling

The property `dateOfDrilling:TM_Period` describes the time period during which drilling of the borehole occurred.

8.7.1.4.4 startPoint

The property `startPoint:BoreholeStartPointCode` provides a term from a controlled vocabulary indicating the named position relative to ground surface where the borehole commenced. (e.g., natural ground surface, open pit floor, underground, offshore)

8.7.1.4.5 inclinationType

The property `inclinationType:BoreholeInclinationCode` contains a term from a controlled vocabulary indicating the inclination type of the borehole. Appropriate terms would include vertical; inclined up; inclined down, horizontal.

8.7.1.4.6 boreholeMaterialCustodian

The property `boreholeMaterialCustodian` is an association between `BoreholeDetails` and a `CIT:CI_ResponsibleParty` describing the organisation that is custodian of the drilled material recovered from the borehole.

8.7.1.4.7 purpose

The property `purpose:BoreholePurposeCode` contains a term from a controlled vocabulary describing the purpose for which the borehole was drilled. e.g., site investigation, mineral exploration, hydrocarbon exploration, water resources.

8.7.1.4.8 dataCustodian

The `dataCustodian` is an association between a `BoreholeDetails` and a `CIT:CI_ResponsibleParty` describing the custodian (person or organisation) that is the custodian of data pertaining to this borehole.

8.7.1.4.9 boreholeLength

The property `boreholeLength` (`SWE::Quantity`) contains a measurement (a value and a unit of measurement) corresponding to the "length" of a borehole determined by the data provider (i.e., "length" can have different sources, like drillers measurement, loggers measurement, survey measurement, etc.).

8.7.1.5 OriginPosition

A borehole `OriginPosition` is a feature corresponding to the start point of a borehole log. This may correspond to the borehole collar location (e.g., kelly bush).

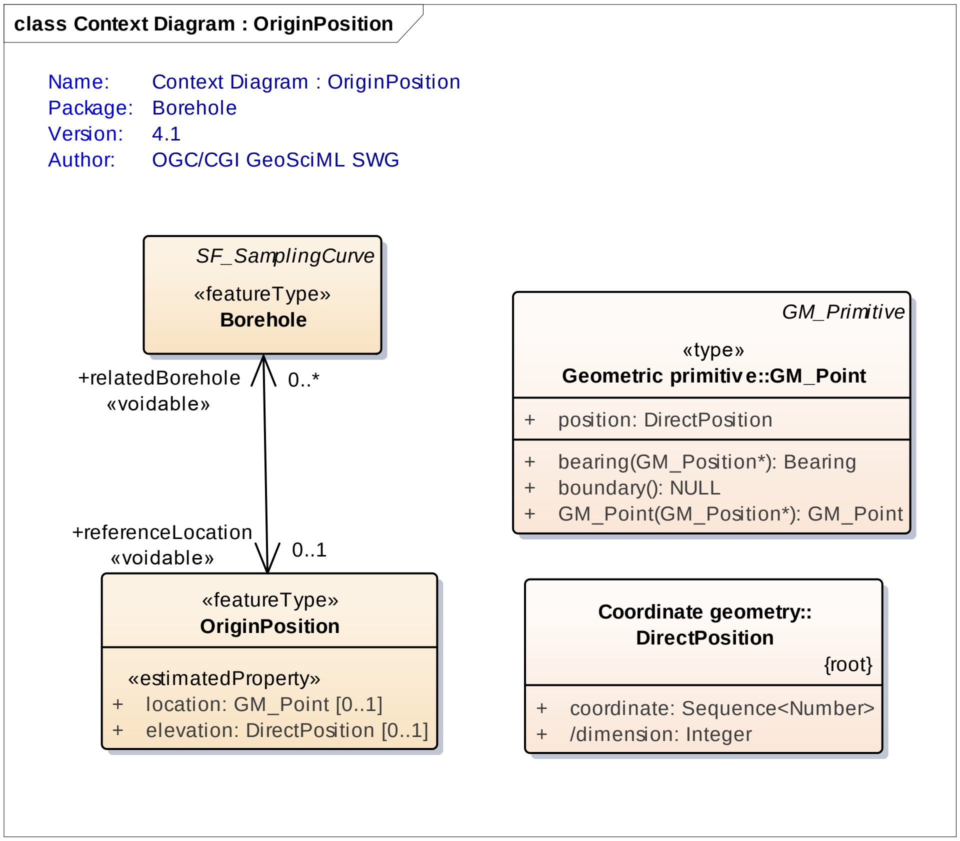


Figure 81 - Origin position context diagram.

If a text description of the location is available, it should be reported in the description property, inherited from `GM:GFI_Feature`.

8.7.1.5.1 location

The property location contains a geometry corresponding to the location of the borehole collar.

If no `GEO::GM_Point` is available, an OGC nil value shall be used.

/req/gsml4-borehole/borehole-position-null	If no `GM_Point` is available, an OGC nil value SHALL be used.

In situations where the origin position changes over the life of the borehole (e.g., due to subsidence or destruction of the original collar), the origin position should be updated to the new location.

8.7.1.5.2 elevation

Implementers delivering 3-D origin locations should provide an elevation to improve interoperability.

/req/gsml4-borehole/borehole-3d	Implementers delivering 3-D origin locations SHOULD provide an elevation.

The `elevation:DirectPosition` property is a compromise approach to supply elevation explicitly for location; this is to allow for software that cannot process 3-D `GM_Point`. Null shall be used if elevation is unknown. A `DirectPosition` shall have a dimension of 1, and CRS will be a "vertical" CRS (e.g. EPSG CRSs in the range 5600-5799).

/req/gsml4-borehole/borehole-elevation-dim	Origin elevation SHALL be a geometry with a dimension of 1.

/req/gsml4-borehole/borehole-elevation-CRS	Origin elevation srsName identifier SHALL be a vertical CRS having an EPSG in the range 5600-5799.

8.7.2 **GeoSciML Borehole vocabularies**

Vocabularies used in Borehole package are listed in Table 7.

Table 7 - GeoSciML Borehole vocabularies.

Vocabulary	**Description**
BoreholeDrillingMethodCode	This class is an indicative placeholder only for a vocabulary of terms describing the borehole drilling method. Users are encouraged to use a vocabulary of terms managed by the CGI vocabularies working group. (e.g., auger, hand auger, air core, cable tool, diamond core, rotary air blast, etc.).
BoreholeInclinationCode	This class is an indicative placeholder only for a vocabulary of terms describing the general orientation of a borehole. Users are encouraged to use a vocabulary of terms managed by the CGI vocabularies working group. For example: • vertical • horizontal • inclined up • inclined down
BoreholePurposeCode	Place holder for a vocabulary containing terms describing the purpose for which the borehole was drilled. e.g., mineral exploration, water pumping,

	site evaluation, stratigraphic research, etc.
BoreholeStartPointCode	This class is an indicative placeholder only for a vocabulary of terms describing the location of the start of a borehole. Users are encouraged to use a vocabulary of terms managed by the CGI vocabularies working group. Examples may include: • 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 • from pre-existing hole - new drill hole spudded off the wall of an existing hole

8.8 GeoSciML LaboratoryAnalysis-Specimen Requirements Class (Normative)

Requirements Class	
/req/gsml4-lab-analysis	
Target type	Encoding
Dependency	/req/gsml4-core
Dependency	ISO 19103 Conceptual Model Language
Dependency	ISO 19107 Spatial Schema
Dependency	ISO-19156 Observations and Measurements (OGC Topic 20)
Dependency	SWE Common 2.0 08-094r1 Clause 7
Dependency	ISO 19108 Temporal Schema
Dependency	ISO 19115-3 Citation
Requirement	**/req/gsml4-lab-analysis/sampledFeature** OM::SF_SamplingFeature::sampledFeature SHALL not be an instance of OM::SF_SamplingFeature.
Requirement	**/req/gsml4-lab-analysis/accuracy-measure** For analytical error and detection limits, both DQ_QuantitativeAttributeAccuracy::nameOfMeasure and DQ_QuantitativeAttributeAccuracy::result SHALL NOT be null.
Requirement	**/req/gsml4-lab-analysis/accuracy-vocabulary** The value of DQ_Element:nameOfMeasure SHOULD be a term from a controlled vocabulary.
Recommendation	**/req/gsml4-lab-analysis/image-url** The identifier of the image should be a HTTP URI referring to a representation of the image.
Recommendation	**/req/gsml4-lab-analysis/image-process**

	The image om:procedure SHOULD make reference to a camera.
Recommendation	**/req/gsml4-lab-analysis/outcrop-pattern** Observations at outcrop SHOULD be encoded using the pattern described at clause 8.8.5

The LaboratoryAnalysis-Specimen application model extends the ISO19156 model for Observations, Measurements and Sampling. It specifically describes processes and results related to the analysis of (geological) samples using instruments, commonly in a laboratory environment. The design of this package is also informed by the MOLES v3 data model [21].

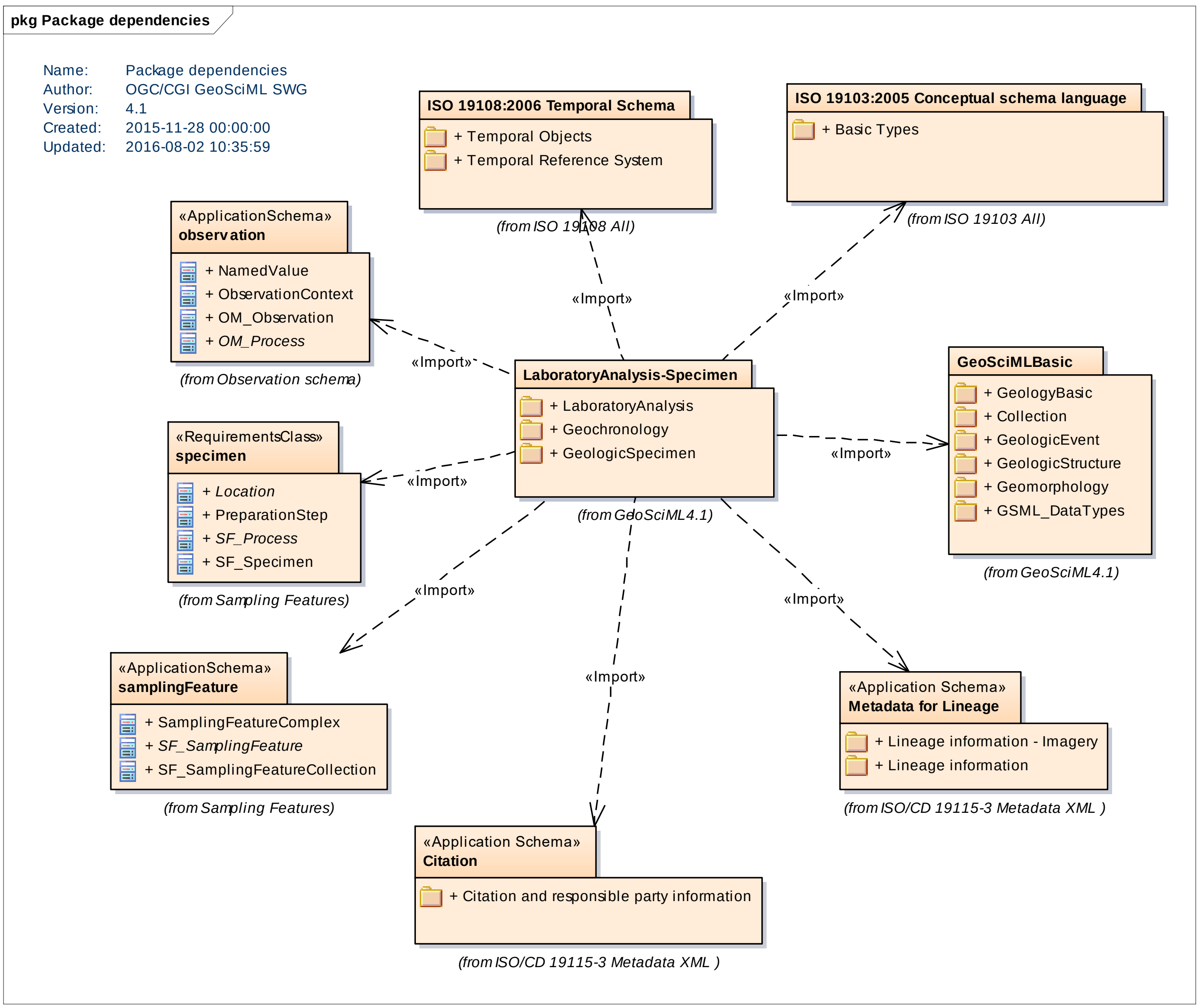


Figure 82 - LaboratoryAnalysis and Specimen dependencies.

8.8.1 **LaboratoryAnalysis**

The `LaboratoryAnalysis` leaf package describes processes, instruments and result quality associated with quantitative analysis of samples. It is an application of ISO19156 Observations and Measurements with supplemental requirements over some of O&M classes.

8.8.1.1 SF_SamplingFeature::sampledFeature

The "`sampledFeature`" association links the `OM::SF_SamplingFeature` to the feature which the sampling feature was designed to sample. The target of this association shall not be a sampling feature. It is shall a real-world feature from an application domain.

/req/gsml4-lab-analysis/sampledFeature	`OM::SF_SamplingFeature::sampledFeature` SHALL not be an instance of `OM::SF_SamplingFeature`.

8.8.1.2 OM_Observation::resultQuality

`OM::OM_Observation::resultQuality::DQ_QuantitativeAttributeAccuracy` attribute shall be used to represent analytical errors and detection limits for each analytical measurement.

At least "`nameOfMeasure`" and "`result`" shall be used when delivering `om:resultQuality`.

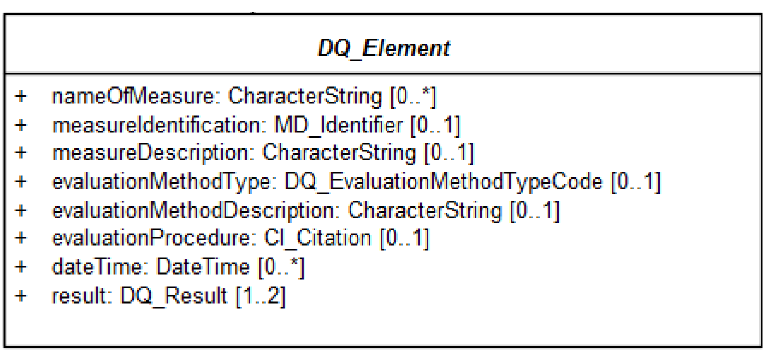


Figure 83 - DQ_Element from ISO19115:2003.

/req/gsml4-lab-analysis/accuracy-measure	For analytical error and detection limits, both `DQ_QuantitativeAttributeAccuracy::nameOfMeasure` and `DQ_QuantitativeAttributeAccuracy::result` SHALL NOT be null.

The CharacterString in "`nameOfMeasure`" should be a term from a controlled vocabulary.

/req/gsml4-lab-analysis/accuracy-vocabulary	The value of `DQ_Element::nameOfMeasure` SHOULD be a term from a controlled vocabulary.

8.8.1.3 OM_Observation::parameter

Analytical methods are very varied and a single model cannot capture all the intricacies of all methods used in geoscience. Communities that need to report specific parameters that are not covered by this specification can use NamedParameter.

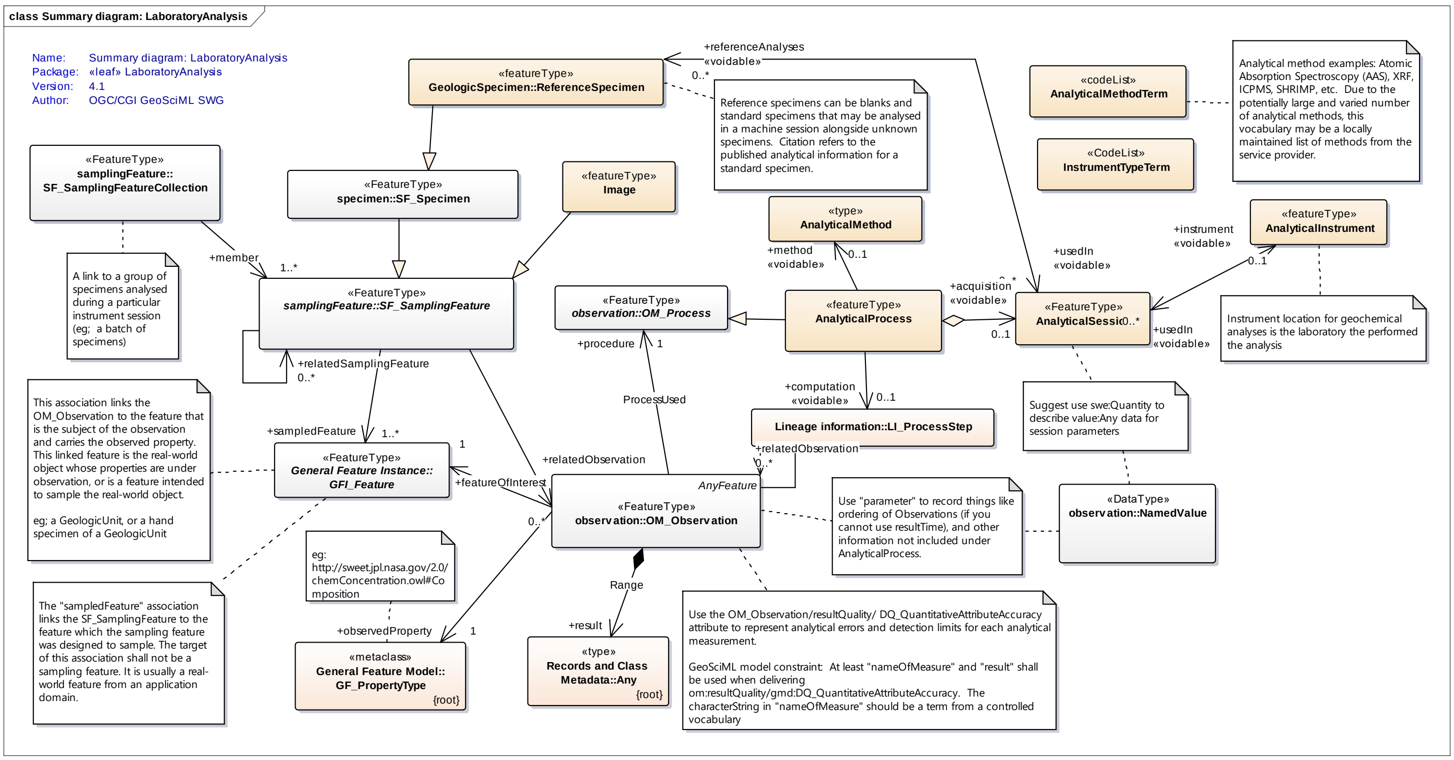


Figure 84 - Laboratory analysis summary diagram.

8.8.1.4 AnalyticalInstrument

The analytical instrument is the category of instrument used to perform an analytical measurement or observation.

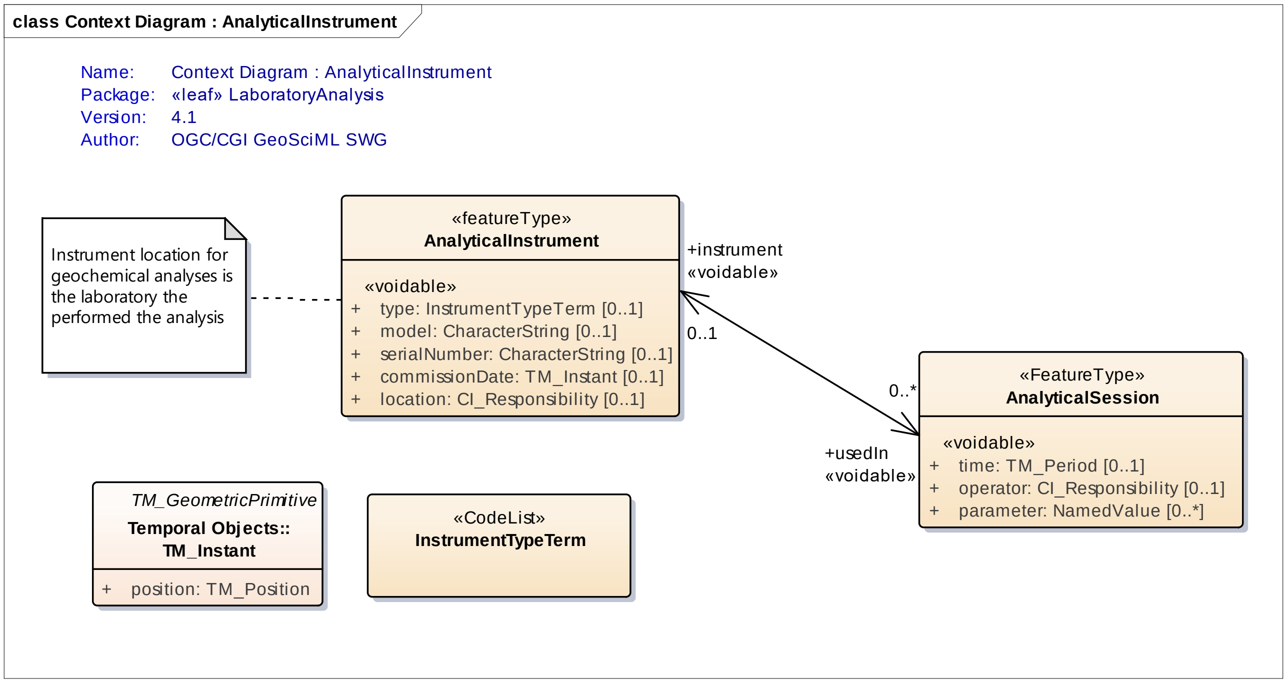


Figure 85 - Analytical instrument context diagram.

8.8.1.4.1 type

The property `type:InstrumentTypeTerm` reports a term from a controlled vocabulary that describes the category of instrument used in an analytical session (e.g., XRF, ICPMS, SHRIMP, etc.).

8.8.1.4.2 model

The property `mode:Primitive::CharacterString` contains a string identifying the model of instrument used. (e.g., instrument type = XRD, model = Siemens Diffraktometer D500).

8.8.1.4.3 serialNumber

The property `serialNumber:Primitive::CharacterString` contains a string that contains the serial number of the machine used in an analytical session.

8.8.1.4.4 commissionDate

The property `commissionDate` is an association between an `AnalyticalInstrument` and a `TM_Instant` corresponding to the date of the commissioning of an instrument.

8.8.1.4.5 location

The property `location` is an association between an `AnalyticalInstrument` and a `CIT:Responsibility` describing the owner and the location of an instrument.

8.8.1.4.6 usedIn

The property `usedIn` is an association between an `AnalyticalInstrument` and an `AnalyticalSession` identifying an analytical sessions which used this instrument.

8.8.1.5 AnalyticalSession

This feature type describes the time and operator of a particular laboratory analytical session. `AnalyticalSession` also has associated links to the type of instrument and analytical method used, processing steps applied to data collected during a session, and instrument parameters unique to that session.

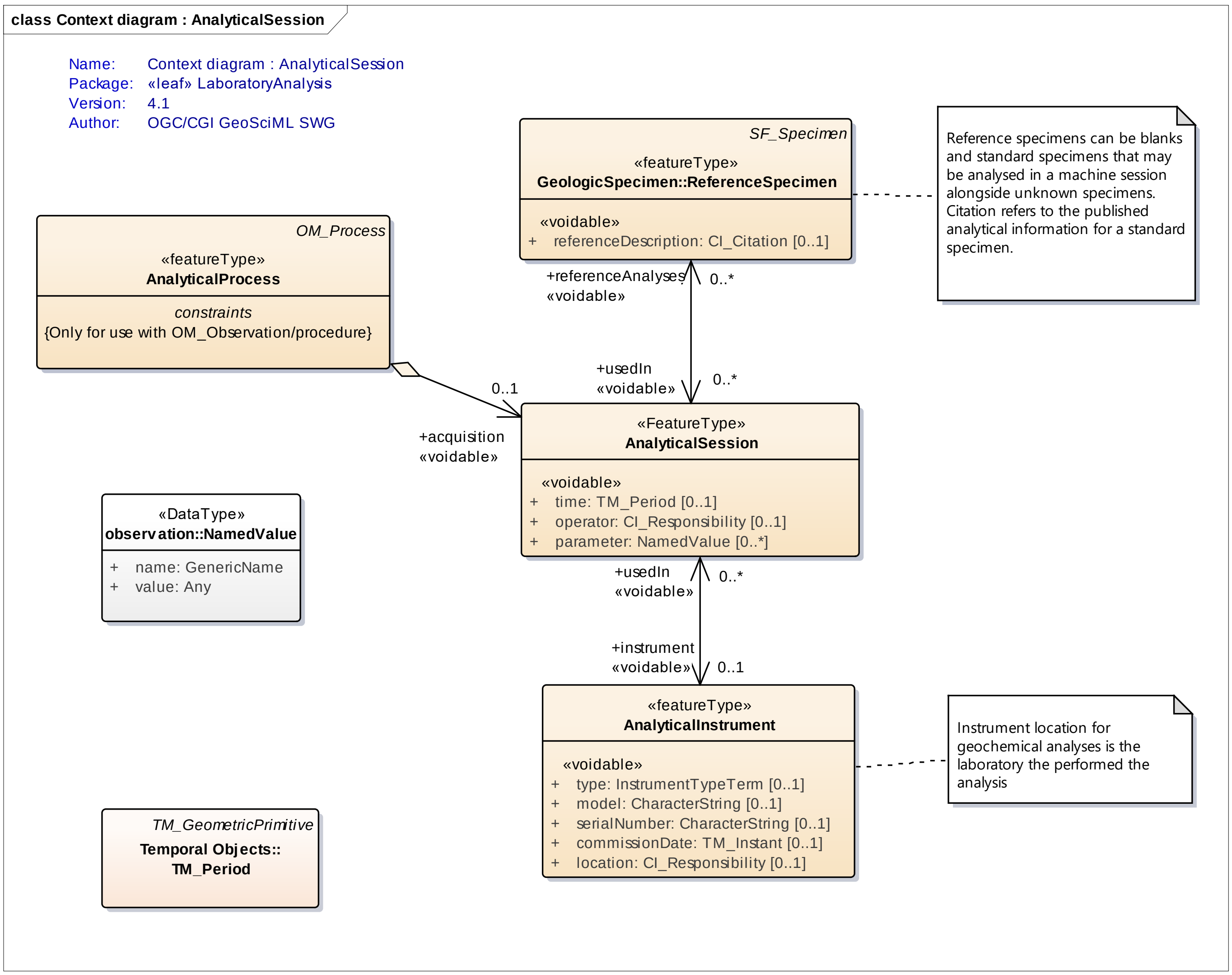


Figure 86 - Analytical session context diagram.

8.8.1.5.1 time

The property `time` is an association between an `AnalyticalSession` and a `TM_Period` describing the time period during which the analysis was performed.

8.8.1.5.2 operator

The property `operator` is an association between an `AnalyticalSession` and a `CIT:CI_Responsability` describing the operator or organisation responsible for the analytical session.

8.8.1.5.3 parameter

The property `parameter` (`OM::NamedValue`) contains a name/value pair to describe arbitrary environmental or instrument setting parameters that apply to an entire analytical session (e.g., voltage, current, temperature, vacuum). The "name" attribute of `NamedValue` is a term from a controlled vocabulary.

8.8.1.5.4 instrument

The property `instrument` is an association between an `AnalyticalSession` and an `AnalyticalInstrument` that describes the instrument used in the analytical session.

8.8.1.5.5 referenceAnalysis

The property `referenceAnalysis` is an association between an `AnalyticalSession` and a `ReferenceSpecimen` that describes a reference specimen (i.e., standards, blanks) used in the analytical session.

8.8.1.6 AnalyticalProcess

An analytical process is a concrete implementation of `OM::OM_Process` and describes the steps and methods used in an analytical session. It links to an analytical session (data acquisition) or a computational process which produce analytical results.

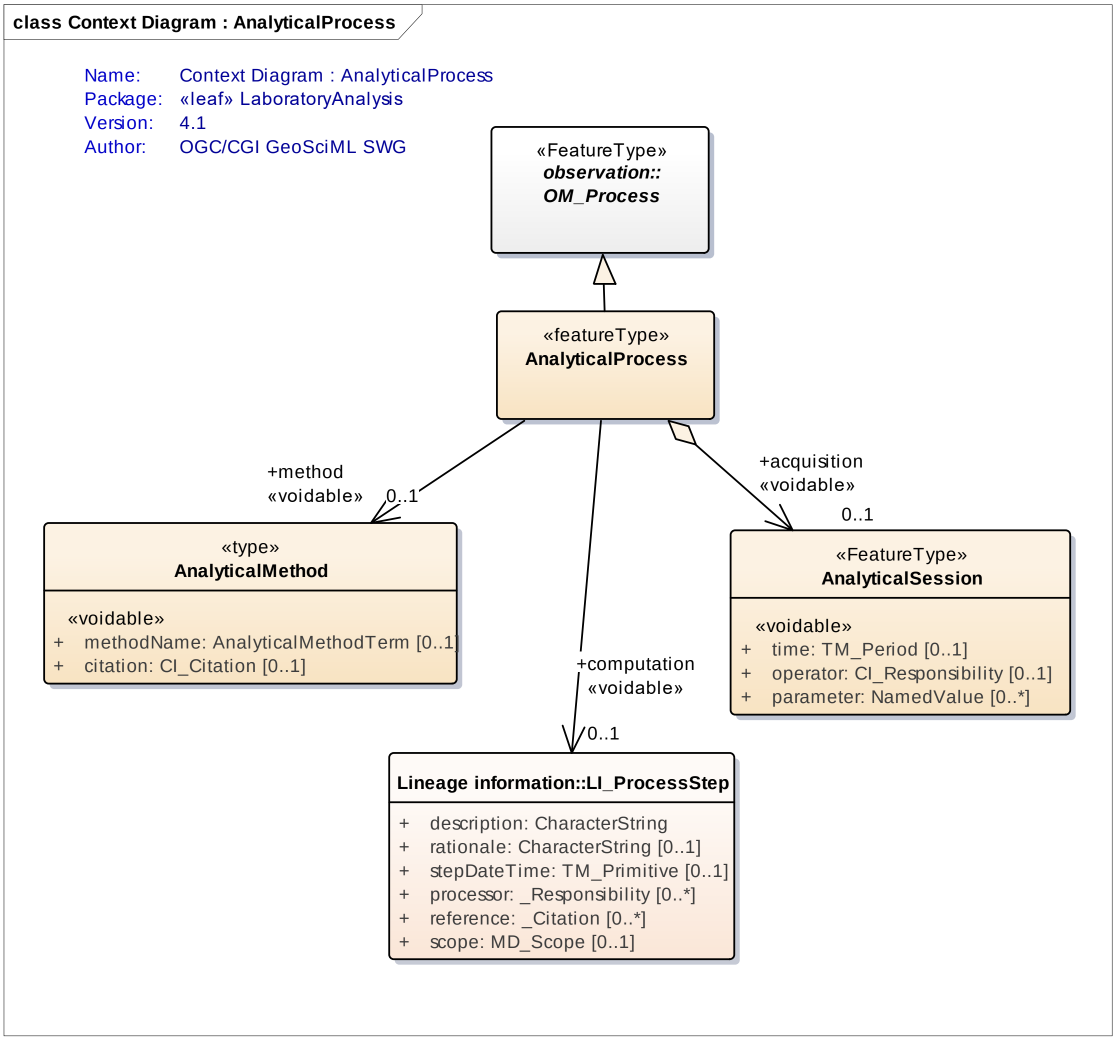


Figure 87 - Analytical process

8.8.1.6.1 method

The property `method` is an association that links an `AnalyticalProcess` to an `AnalyticalMethod` that describes the type of analytical method used to make an observation.

8.8.1.6.2 acquisition

The property `acquisition` is an association that links an `AnalyticalProcess` to an `AnalyticalSession` that describes the analytical session (e.g., laboratory session) in which an observation was made and data acquired.

8.8.1.6.3 computation

The `computation` property is an association between an `AnalyticalProcess` and a `CIT:ProcessStep` that describes the computational process associated with the process.

8.8.1.7 AnalyticalMethod

The `AnalyticalMethod` provides the name, and published citation, of the analytical method used in an analytical session.

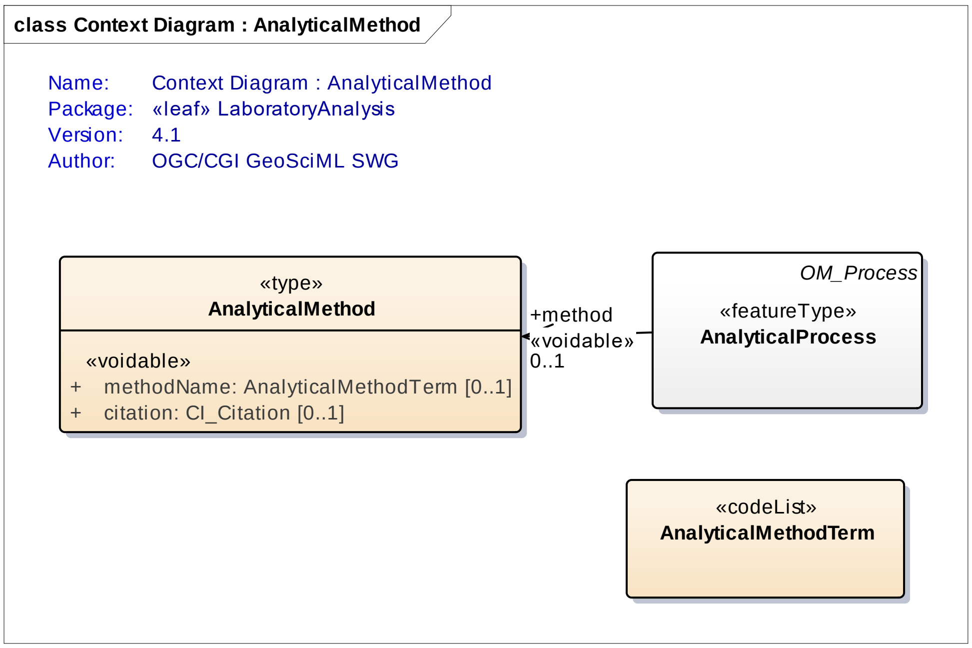


Figure 88 - Analytical method

8.8.1.7.1 methodName

The property `methodName:AnalyticalMethodTerm` contains a term from a controlled vocabulary that describes an analytical method used in a session (e.g., XRF mass spectrometry, ICPMS, SHRIMP geochronology).

8.8.1.7.2 citation

The `citation` property is an association between an `AnalyticalMethod` and a `CIT:CI_Citation` describing a published description of a particular analytical method (e.g., a standard operating procedure document).

8.8.1.8 Image

The `Image` feature type is used to describe images of sampling features, for example, photographs of ion microprobe grain mounts.

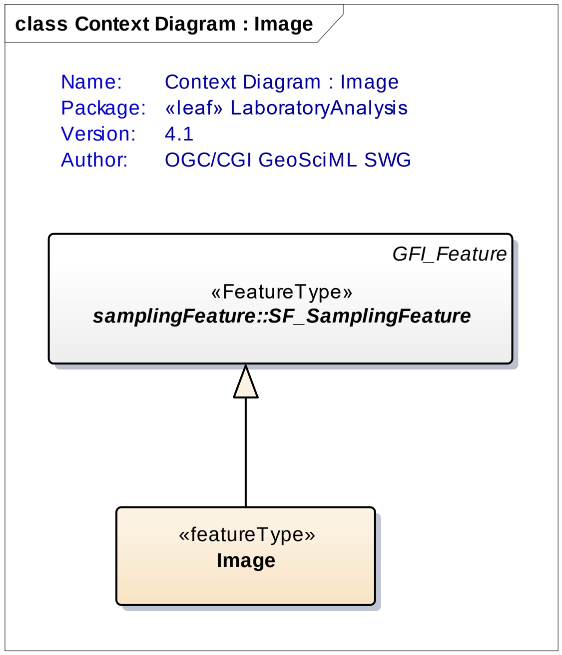


Figure 89 - Image

When the image is available online, the identifier of the image, a HTTP URI, should point to one or more representation of that image.

/req/gsml4-lab-analysis/image-url	The identifier of the image SHOULD be a HTTP URI referring to a representation of the image.

The `samplingMethod` (inherited from `OM::SF_SamplingFeature`) for an image should be an identifier of a camera.

/req/gsml4-lab-analysis/image-process	The image om:procedure SHOULD make reference to a camera.

8.8.2 Geochronology

The Geochronology model allows the delivery of geochronological interpretations by describing:

1) a `OM::SF_Specimen` (e.g., a rock sample)
2) a related collection of sampling features within that specimen (e.g., ion probe burn spots, mineral separates),
3) and a `GeochronologicInterpretation` related to that sampling collection.

Each member of the sampling collection has a related OM_Observation/result(s).

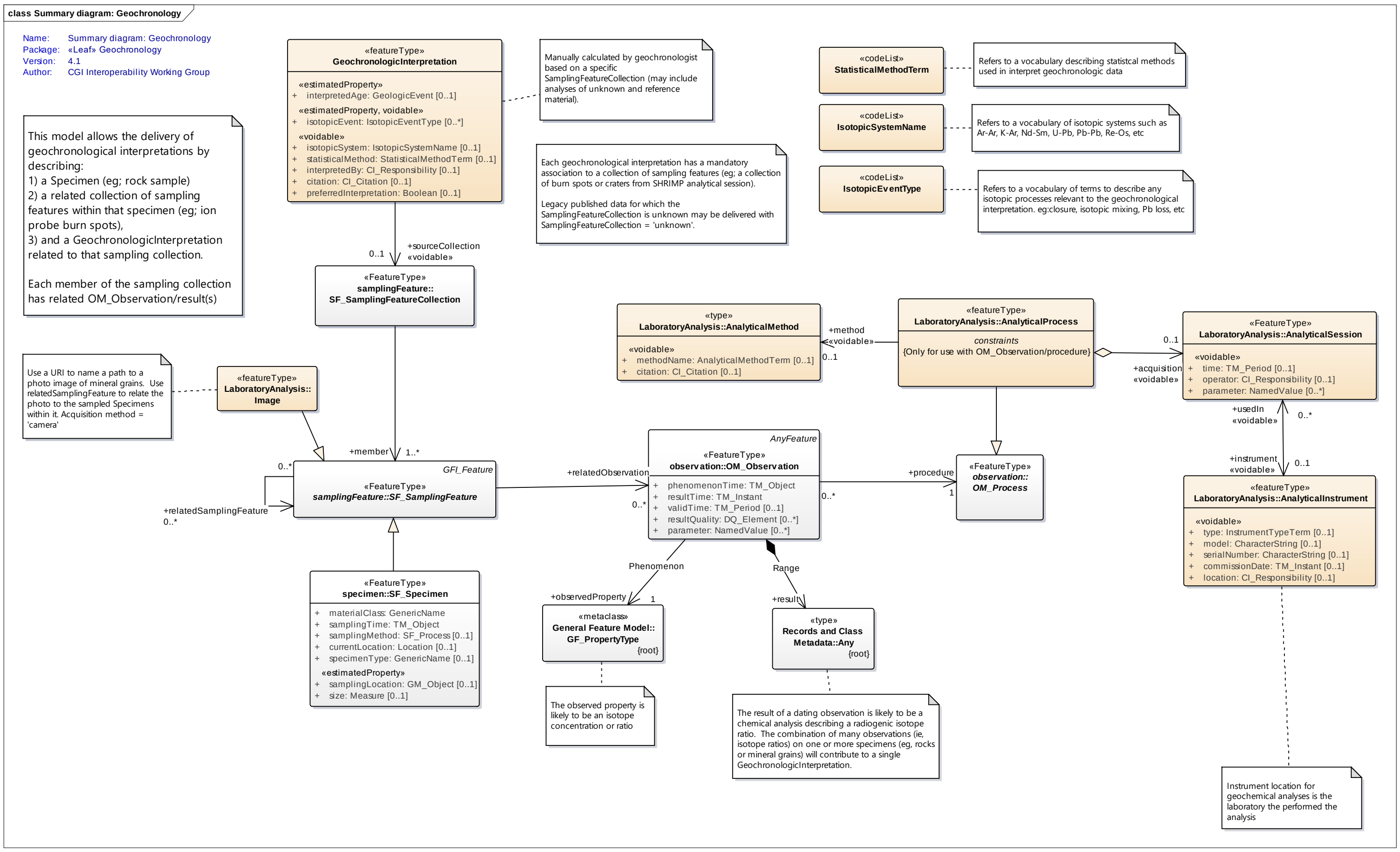


Figure 90 - Summary diagram of geochronology.

8.8.2.1 GeochronologicInterpretation

A `GeochronologicInterpretation` is an interpretation made by a geologist of the age of a specimen made by statistical analysis of a collection of observations. A geologic specimen may have multiple geochronological interpretations made on it, each related to a different observation/result collection.

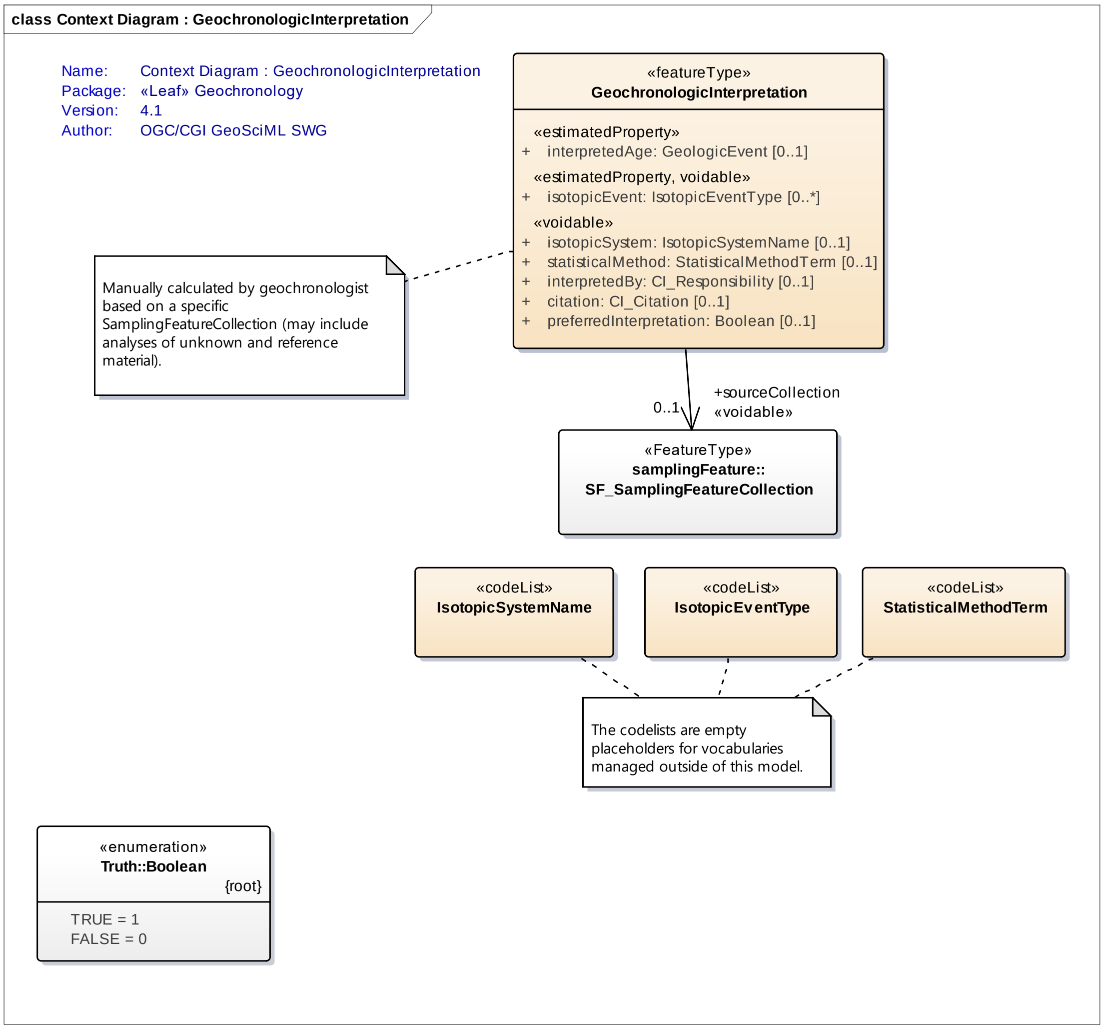


Figure 91 - Geochronologic interpretation context diagram.

8.8.2.1.1 interpretedAge

The `interpretedAge` property is an association between a `GeochronologicInterpretation` and a `GeologicEvent` that describes the dated event, process and environment.

For example:

- Event age = 350 Ma +/- 3 Ma.
- Event process = intrusion, extrusion, metamorphism, etc.
- Event environment = plutonic, subaerial, marine, etc.

8.8.2.1.2 isotopicEvent

The `isotopicEvent:IsotopicEventType` contains a term from a controlled vocabulary that describes any isotopic events that are relevant to the interpretation. e.g., closure, isotopic mixing, Pb loss, etc.

8.8.2.1.3 isotopicSystem

The property `isotopicSystem:IsotopicSystemName` contains a term from a controlled vocabulary that describes the isotopic system used to calculate geochronological age. A vocabulary would contain values such as: Ar-Ar, K-Ar, Nd-Sm, Pb-Pb, Rb-Sr, Re-Os, U-Pb, etc.

8.8.2.1.4 statisticalMethod

The property `statisticalMethod:StatisticalMethodTerm` contains a term from a controlled vocabulary that describes the statistical method used to interpret the results. (e.g., weighted mean, median, concordia, discordia, etc)

8.8.2.1.5 interpretedBy

The property `interpretedBy` is an association between a `GeochronologicInterpretation` and a `CIT:CI_Responsability` describing the party responsible for this interpretation.

8.8.2.1.6 citation

The `citation` property is an association between a `GeochronologicInterpretation` and a `CIT:CI_Citation` that describes authors and other reference information for an interpreted age.

8.8.2.1.7 preferredInterpretation

The property `preferredInterpretation:Primitive::Boolean` indicates whether this interpretation is the preferred interpretation (i.e., the analytical data may be reinterpreted).

8.8.2.1.8 sourceCollection

The property `sourceCollection` is an association between a `GeochronologicInterpretation` and an `OM::SF_SamplingFeatureCollection` that lists a collection of `OM::SF_SamplingFeature` (e.g., a collection of burn spots or craters from a SHRIMP analytical session). When legacy published data for which the `SamplingFeatureCollection` is unknown, it may be delivered with `SamplingFeatureCollection` = 'unknown'.

8.8.3 GeologicSpecimen

The `GeologicSpecimen` package extends the ISO19156 O&M model, and describes processes relevant to the sampling, preparation, and analysis of geologic specimens.

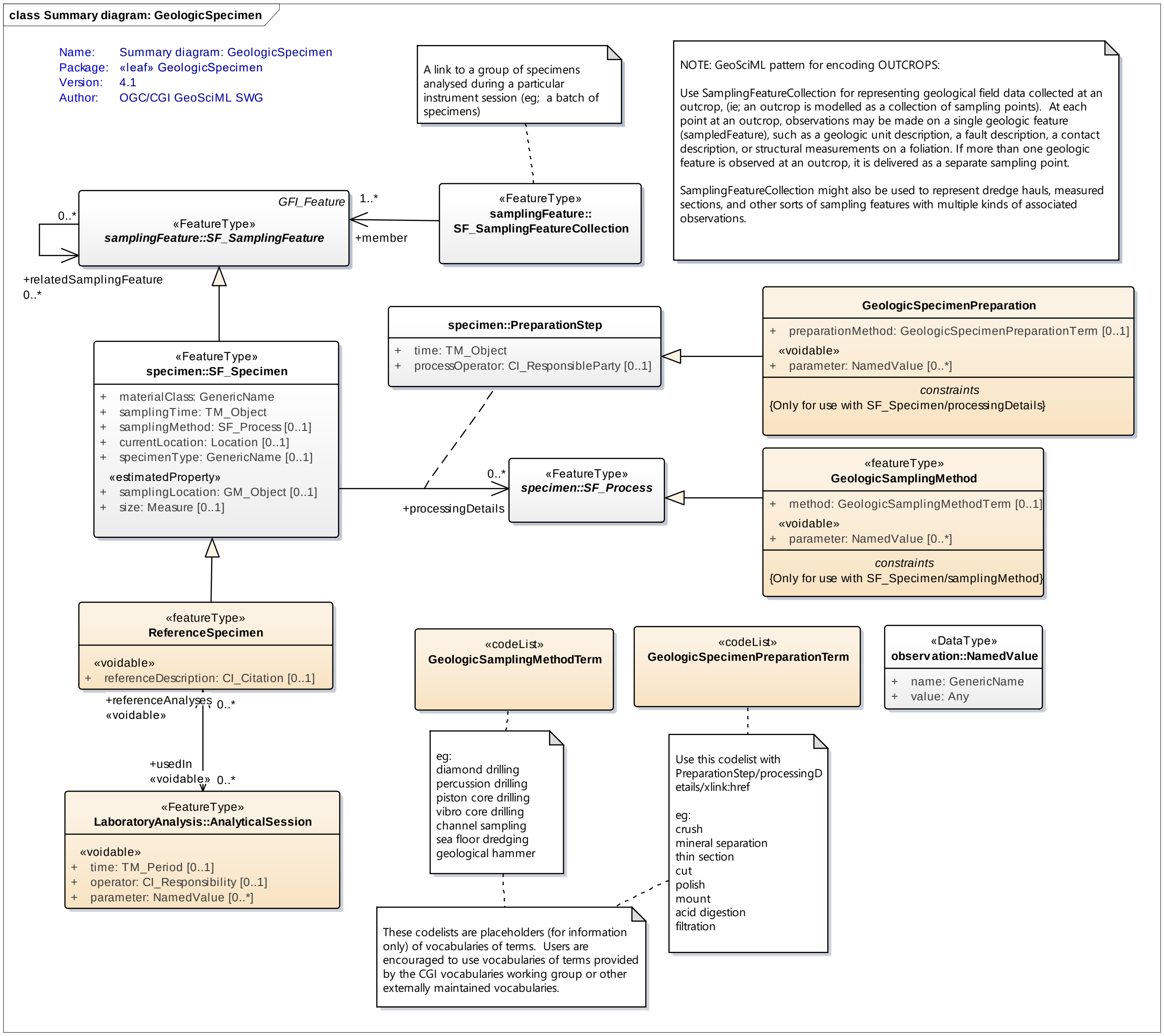


Figure 92 - Geologic specimen summary diagram.

8.8.3.1 ReferenceSpecimen

A reference specimen is a specimen with known or accepted values of some property. The citation property describes the location of a published description of these values. Reference specimens include analytical blanks. `ReferenceSpecimens` are used in quality control procedures to assess method reproducibility.

Analytical results from a reference specimen analysed during an AnalyticalSession are delivered in the same way as the results of other specimens analysed in that session.

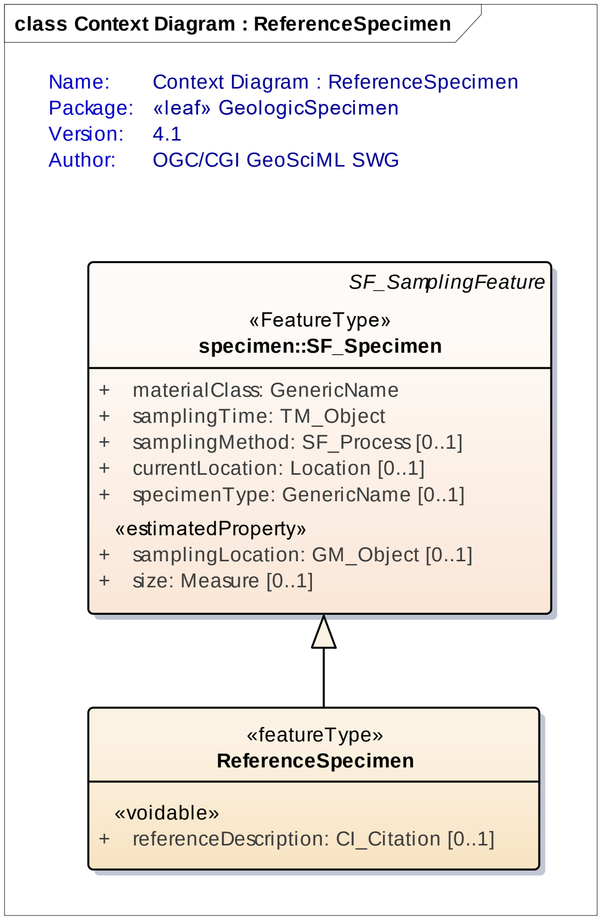


Figure 93 - Reference specimen context diagram.

8.8.3.1.1 referenceDescription

The property referenceDescription is an association between a ReferenceSpecimen and a CIT:CI_Citation that references a citation of published analytical results for this standard reference specimen.

8.8.3.1.2 usedIn

The property usedIn is an association between a ReferenceSpecimen and an AnalyticalSession in which the reference specimen was used.

8.8.3.2 GeologicSpecimenPreparation

GeologicSpecimenPreparation is an extension of ISO Specimen::preparationStep to allow details of preparation steps to be delivered (e.g., filtration and mesh size, chemical additives, crushing methods, drying parameters, etc.).

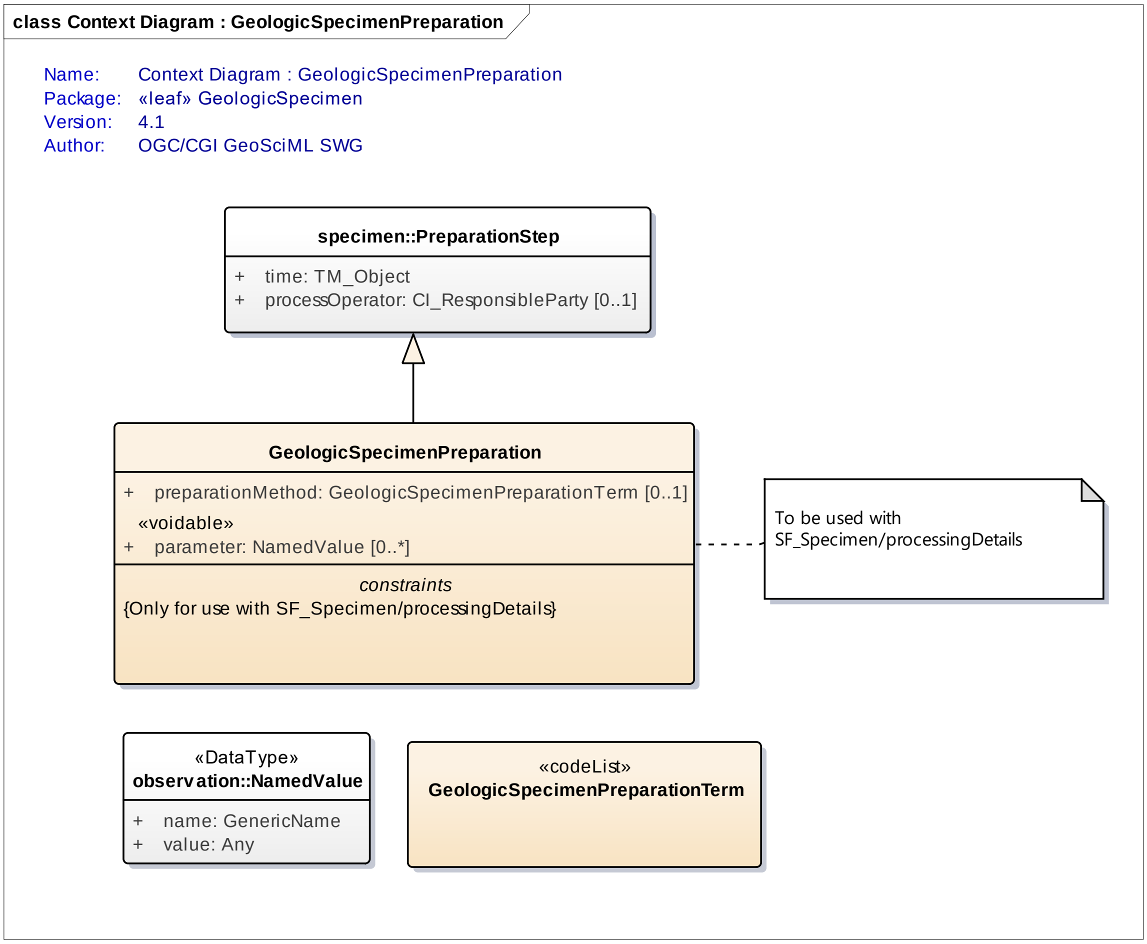


Figure 94 - Geologic specimen preparation context diagram.

8.8.3.2.1 preparationMethod

The `preparationMethod:GeologicSpecimenPreparationTerm` contains a term from a controlled vocabulary that describes the method employed for the preparation of a geologic specimen for further analysis.

8.8.3.2.2 parameter

The property `parameter` (`OM::NamedValue`) contains name/value pair to describe arbitrary parameters used in this preparation step (e.g., mesh size in a sieving process, type of chemical additives, parameters in a mineral separation process). The "`name`" attribute of `NamedValue` shall be a term from a controlled vocabulary.

8.8.3.3 GeologicSamplingMethod

`GeologicSamplingMethod` is an implementation of `OM::SF_Process` to describe the method used to obtain a geologic specimen.

Examples include:

- diamond drilling

- percussion drilling
- piston core drilling
- vibro core drilling
- channel sampling
- sea floor dredging
- outcrop sampling

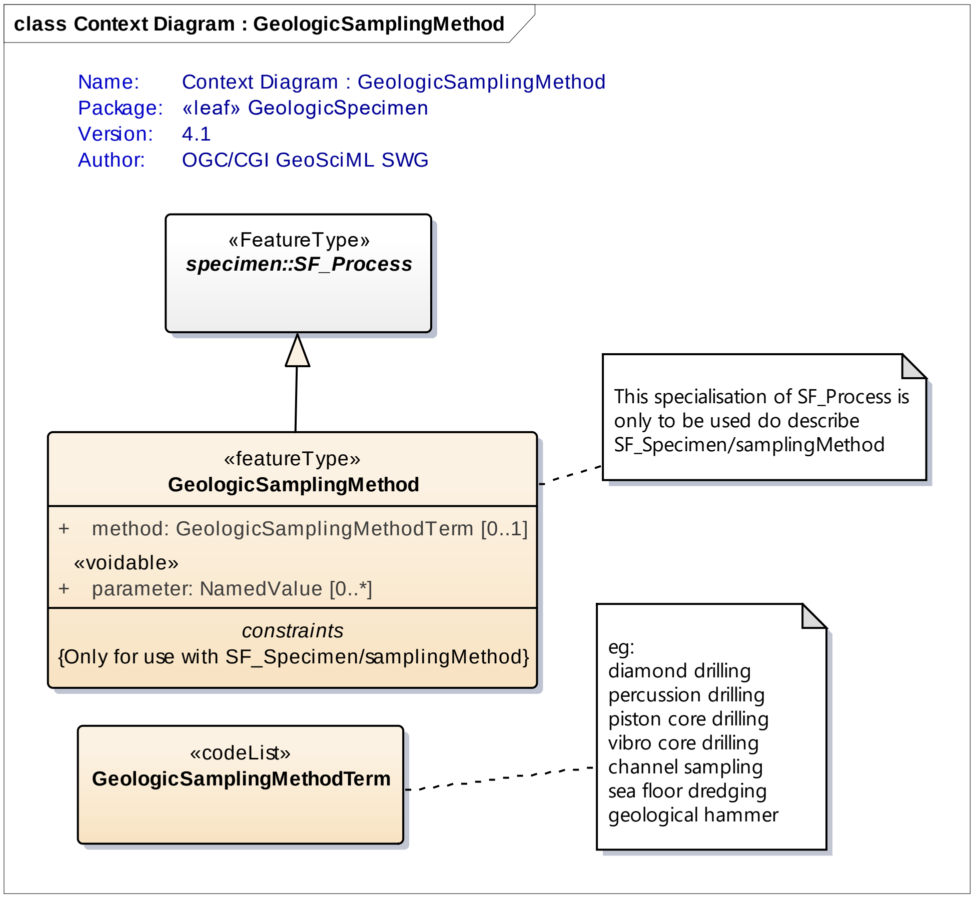


Figure 95 - Geologic sampling method

8.8.3.3.1 method

The property `method:GeologicSamplingMethodTerm` is a term from a controlled vocabulary that describes the process used to obtain or create a geologic specimen. e.g., diamond drilling, percussion drilling, piston core drilling, vibro core drilling, channel sampling, sea floor dredging, crushing, mineral separation, melting, outcrop sampling.

8.8.3.3.2 parameter

The property `parameter` (`OM::NamedValue`) contains a name/value pair to describe arbitrary parameters used in the sampling process. The "`name`" attribute of `NamedValue` shall be a term from a controlled vocabulary.

8.8.4 **GeoSciML LaboratoryAnalysis-Specimen vocabularies**

Vocabularies used in the LaboratoryAnalysis-Specimen package are listed in Table 78:

Table 8 - Laboratory analysis and specimen vocabularies.

Vocabulary	Description
AnalyticalMethodTerm	Refers to a vocabulary of terms describing the analytical method used in an analytical session (e.g., XRF mass spectrometry, ICPMS, SHRIMP geochronology).
InstrumentTypeTerm	Refers to a vocabulary of Instrument types (e.g., XRF, ICPMS, SHRIMP, etc.).
IsotopicEventType	Refers to a vocabulary of terms to describe any isotopic processes relevant to the geochronologic interpretation. E.g. closure, isotopic mixing, Pb loss, etc.
IsotopicSystemName	Refers to a vocabulary of isotopic systems such as Ar-Ar, K-Ar, Nd-Sm, U-Pb, Pb-Pb, Re-Os, etc.
StatisticalMethodTerm	Refers to a vocabulary describing statistical methods used in interpret geochronologic data.
GeologicSamplingMethodTerm	Refers to a vocabulary of terms describing the samplingProcess used to obtain or create the Specimen. e.g., diamond drilling, percussion drilling, piston core drilling, vibro core drilling, channel sampling, sea floor dredging, crushing mineral separation ,melting ,outcrop sampling.
GeologicSpecimenPreparationTerm	Refers to a vocabulary of terms to describe sample preparation applied to geologic specimens, typically in preparation for analytical processes like geochemistry or microscopy. e.g., crush, mineral separation, thin section, cut, polish, mount, acid digestion.

8.8.5 **Outcrop encoding pattern (Informative)**

It is suggested to use `SamplingFeatureCollection` for representing geological field data collected at an outcrop, (i.e., an outcrop is modelled as a collection of sampling points). At each point at an outcrop, observations may be made on a single geologic feature (`sampledFeature`), such as a geologic unit description, a fault description, a contact description, or structural measurements on a foliation. If more than one geologic feature is observed at an outcrop, it is delivered as a separate sampling point.

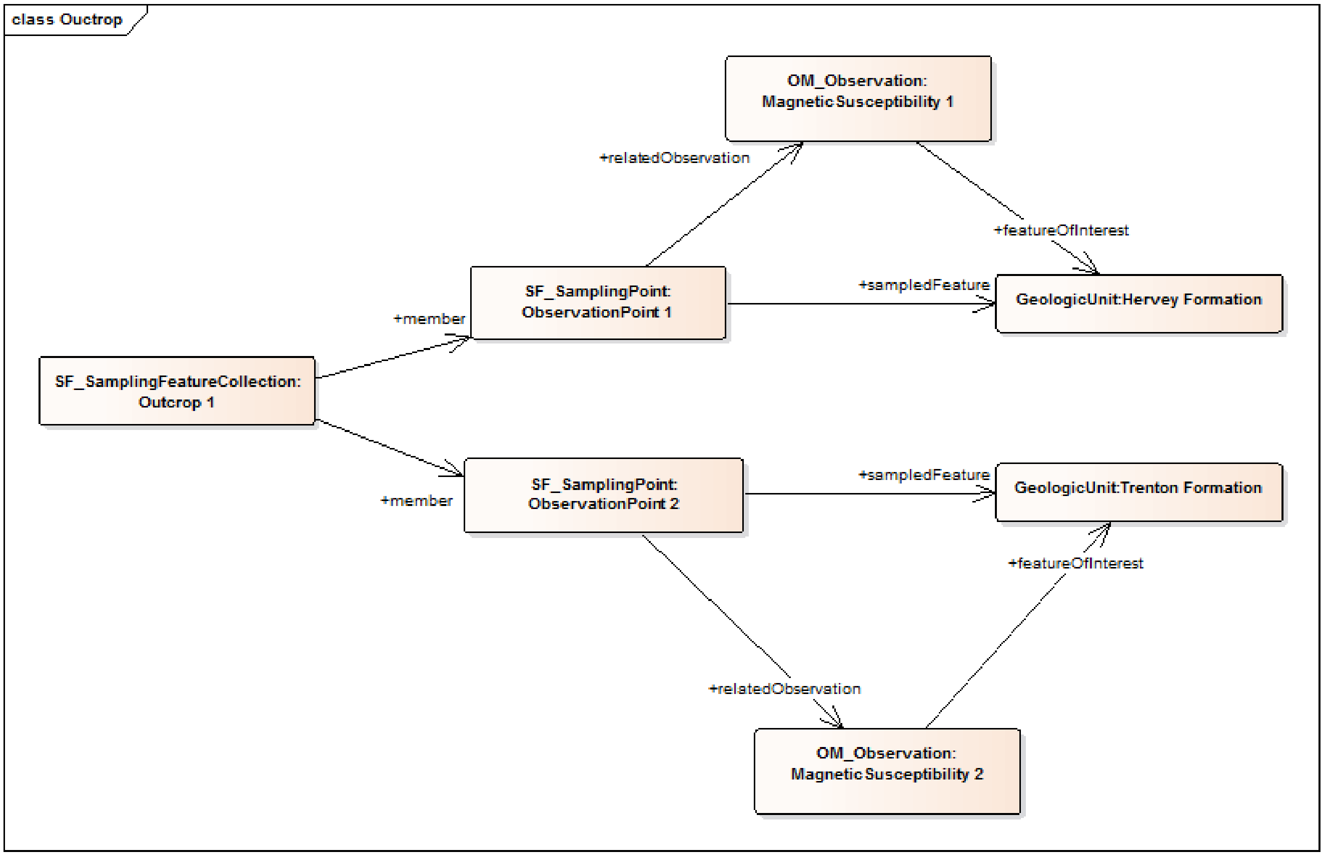


Figure 96 - Outcrop encoding pattern using ISO19156.

`SamplingFeatureCollection` might also be used to represent dredge hauls, measured sections, and other sorts of sampling features with multiple kinds of associated observations.

/req/gsml4-lab-analysis/outcrop-pattern	Observations at outcrop SHOULD be encoded using the pattern described at clause 8.8.5

8.9 GeoSciML Lite Requirements Class (Normative)

Requirements Class	
/req/gsml4-lite	
Target type	Encoding
Dependency	/req/gsml4-conceptual
Dependency	GML Simple Feature SF-0 OGC 10-100r3
Dependency	ISO 8601 (Date and Time format)
Dependency	Linked Open Data
Dependency	RFC 3986 (HTTP URI)
Requirement	**/req/gsml4-lite/geomtype** A dataset SHALL use a single geometry type (Point, Line, Polygon, etc.).
Requirement	**/req/gsml4-lite/string** Properties of type "CharacterString" SHALL contain human readable text.
Recommendation	**/req/gsml4-lite/formal-syntax** Syntax of text in character string properties SHOULD be formalised.
Requirement	**/req/gsml4-lite/datetime** Calendar date and time SHALL be formatted according to ISO 8601.
Requirement	**/req/gsml4-lite/uri** Properties which name end with "_uri" SHALL contain a string conformant to URI format as specified in RFC 3986.
Recommendation	**/req/gsml4-lite/resolvable-uri** Properties containing a valid URI SHOULD be dereferenceable.
Requirement	**/req/gsml4-lite/user-defined** Features delivered with user defined properties SHALL be conformant to GML Simple Feature Level 0.
Requirement	**/req/gsml4-lite/identifier-unique** Identifiers SHALL be unique to a dataset.
Requirement	**/req/gsml4-lite/identifier-uri** Identifiers SHALL be formatted as URI according to RFC 3986.
Recommendation	**/req/gsml4-lite/geologicunitview-identifier** Where possible, GeologicUnitView identifier SHOULD correspond to an instance of GeoSciML MappedFeature.
Requirement	**/req/gsml4-lite/geologicunitview-representativeLithology** representativeLithology_uri value SHALL refer to a controlled concept specifying the

	characteristic or representative lithology of the unit. This may be a concept that defines the super-type of all lithology values present within a GeologicUnit or a concept defining the lithology of the dominant CompositionPart (as defined in GeoSciML) of the unit.
Requirement	**/req/gsml4-lite/geologicunitview-representativeAge** representativeAge_uri value SHALL refer to a controlled concept specifying the most representative stratigraphic age interval for the GeologicUnit. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising the all or part of the feature's history.
Requirement	**/req/gsml4-lite/geologicunitview-representativeOlderAge** representativeOlderAge_uri value SHALL refer to a controlled concept specifying the most representative older value in a range of stratigraphic age intervals for the GeologicUnit. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising the all or part of the feature's history.
Requirement	**/req/gsml4-lite/geologicunitview-representativeYoungerAge** representativeYoungerAge_uri value SHALL refer to a controlled concept specifying the most representative younger value in a range of stratigraphic age intervals for the GeologicUnit. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising the all or part of the feature's history.
Recommendation	**/req/gsml4-lite/geologicunitview-specification** specification_uri value SHOULD refer the GeoSciML GeologicUnit feature that describes the instance in detail.
Recommendation	**/req/gsml4-lite/boreholeview-identifier** identifier SHOULD resolve to a representation of a GeoSciML Borehole.
Requirement	**/req/gsml4-lite/boreholeview-elevation-crs** If present, elevation_srs SHALL resolve to a valid EPSG vertical datum in the range EPSG:5600 to EPSG:5799
Recommendation	**/req/gsml4-lite/boreholeview-parentBorehole-uri** If present, parentBorehole_uri SHOULD resolve to a representation of a GeoSciML borehole.
Recommendation	**/req/gsml4-lite/contactview-identifier** identifier SHOULD correspond to an instance of GeoSciML MappedFeature.
Recommendation	**/req/gsml4-lite/geologicspecimenview-identifier** identifier SHOULD correspond to an instance of GeoSciML GeologicSpecimen.
Recommendation	**/req/gsml4-lite/geomorphologicunitview-identifier** identifier SHOULD correspond to a representation of GeoSciML MappedFeature.

Recommendation	**/req/gsml4-lite/sheardisplacemenstructureview-identifier** identifier SHOULD correspond to a representation of GeoSciML MappedFeature.
Recommendation	**/req/gsml4-lite/siteobservationview-identifier** identifier SHOULD correspond to a representation of OM::OM_Observation.
Requirement	**/req/gsml4-lite/siteobservationview-symbolRotation** If present, the symbolRotation SHALL be a value in the range [0,360[.

GeoSciML Lite is a simplification of parts of GeoSciML and Observations and Measurements (ISO 19156) for map-based applications. It was developed to provide a simple schema to deliver geologic map unit, contact, borehole, located sample, geomorphologic unit and shear displacement structure (fault and ductile shear zone) descriptions in web map services. The intention is to support interoperable map services, for which interoperability is based on a shared data schema and the use of standard vocabulary terms for basic type classification of contacts and faults, age of geologic units and faults, and lithology of geologic units.

Use of standard vocabularies enables map display using a shared legend (symbolization scheme) to achieve visual harmonization of maps provided by different services. In addition, the GeoSciML Lite data structure includes text fields with information for human users browsing a geologic map, a link to a full GeoSciML feature element if available, and a symbol identifier field to enable a user-defined symbolization scheme in each map service.

By linking the simple feature WMS with a GeoSciML WFS, clients can acquire geologic feature descriptions that can be used in web-mapping applications to construct custom legends. Linking to full GeoSciML features allows the Lite schema to be used in a map browsing and query interface to identify and select features for further processing that can be acquired as highly structured, information-rich GML features.

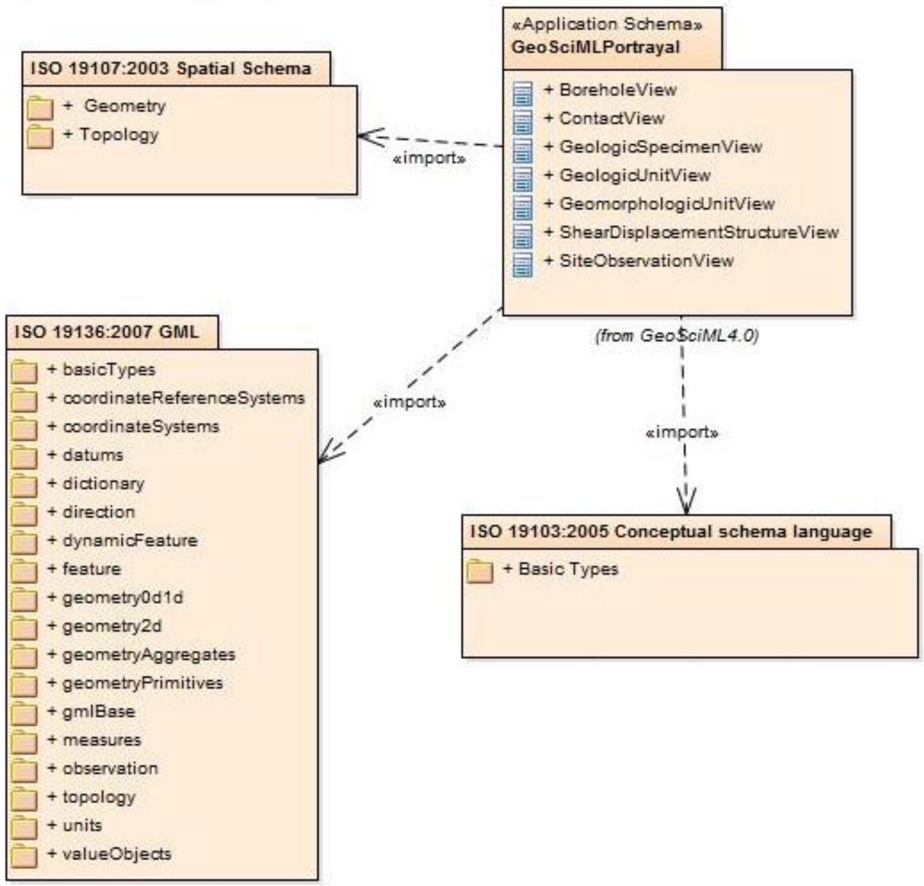


Figure 97 - Package dependency for GeoSciML Lite.

GeoSciML Lite conforms to the Level 0 of the Simple Features Profile for GML (OGC 10-100r, OGC 06-049). The simple features profile supports only a limited subset of possible GML geometry types that may be used to describe feature geographic location and shape. For the purposes of GeoSciML simple features, these include `GEO::Point, GEO::LineString, GEO::Curve, GEO::Polygon`, `GEO::Surface, GEO::MultiPoint, GEO::MultiCurve, GEO::MultiSurface` and multi-geometry types consisting of collections of these base types.

GeoSciML Lite features are analogous to GeoSciML MappedFeatures and O&M sampling features, with additional text attributes for human consumption, a flatted-relation view of the age, and assignment to a single lithology. The Lite schema consists of 'free-text' fields and identifier fields. Best practice is that free text fields will, where possible, contain well-structured summaries of data in a format suitable for reading by the intended users. For instance, an agreed common format like comma-delimited values should be adopted by user communities. Identifier fields should contain identifiers for concepts from a controlled vocabulary (for example CGI Simple Lithology (http://resource.geosciml.org/classifier/cgi/lithology/)) that specify representative thematic properties for a feature. Inclusion of these standardized identifiers enables interoperability across services. Ideally the identifiers should be URIs that can be resolved to obtain machine-processable or human-readable representations of the identified concepts.

In addition, some feature include an (optional) identifier for a specification (`specification_uri`), which is a resource containing a description of that particular feature. In many cases, these descriptions will be the same for all geometries assigned to the same map unit or classified as the same kind of contact or structure. If more complete information is available, different specification descriptions may be associated within subsets of mapped features of the same type that are portrayed with the same symbol. In the most extreme case, each mapped feature occurrence might have a unique description that captures the full spatial variability of a geologic unit or structure. Following the standard patterns of web architecture, the `specification_uri` should be resolvable to obtain one or more representations of that description. For maximum interoperability, one of these representations should be a GeoSciML encoded description of the feature, but other encodings might also be available, for example HTML web pages, other XML schema, or JSON. For those familiar with the GeoSciML Basic package, the `specification_uri` property is equivalent to the `specification` association from MappedFeature to GeologicFeature.

8.9.1 **Property mapping**

Lite properties are mapped to existing GeoSciML or O&M properties. Values from GeoSciML and O&M complex properties are converted into GML SF-0 valid basic types (OGC 10-100r2, Clause 8.4.4.1). Different transformations scenarios are possible:

- The GeoSciML property is already a basic type and the value is used as-is
- A representative element of the complex type is used. For example; only `SWE::Category::value`.
- The value is constructed from several fields merged into a single string.

Lite properties cardinalities are limited to `0..1`, while GeoSciML properties are often multiple. The data provider must then either a) choose one representative value or b) aggregate from the collection of values a new value. Strings will generally be concatenated while numerical values might be averaged or processed in some way to produce a significant value. Some Lite properties are designed to represent explicitly one particular occurrence, such as `GeologicUnitView::representativeOlderAge_uri`, which is the oldest age. Others are more suggestive and require the judgement of the data provider, such as `GeologicUnitView::representativeLithology_uri`. When values are concatenated, they shall be human readable and using simple separators (e.g., commas).

Properties ending with "_uri" <u>shall</u> <u>not</u> have concatenated values. Those properties are designed to fulfill specific query and rendering use cases.

For each GeoSciML Lite view, a table provides the mapping between Lite and GeoSciML properties. The mapping is expressed in OCL syntax as a path from the base type of the view to the property where the value resides in GeoSciML.

For example:

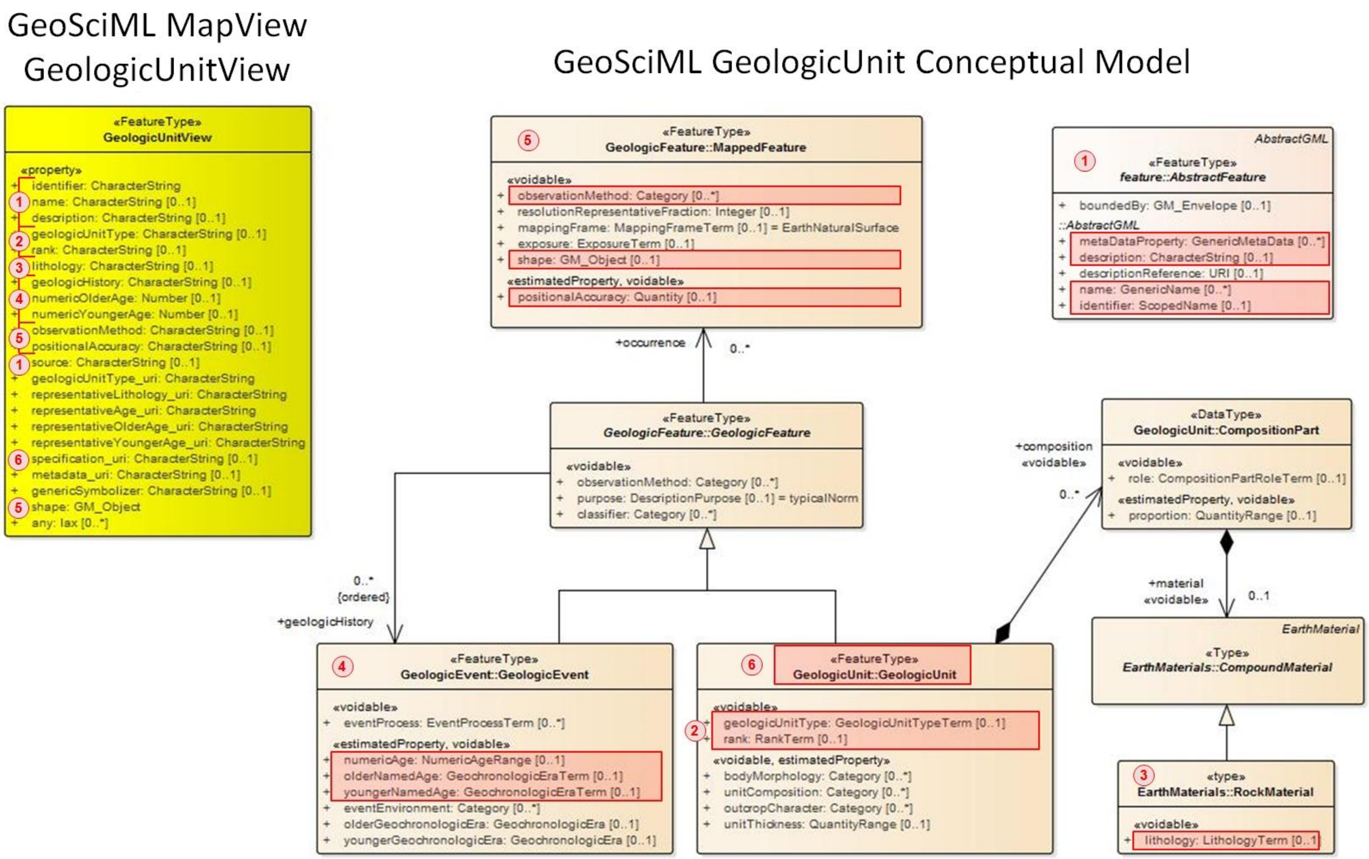


Figure 98 - Mapping of key GeologicUnitView properties to GeoSciML

Figure 98 shows mapping for some `GeologicUnitView` properties. Number 3 on this figure maps `GeologicUnitView::lithology` to `RockMaterial`, which requires a traverse from the base type (`MappedFeature`) to `GeologicUnit`, `CompositionPart` and then `RockMaterial`.

In OCL,

```
specification:GeomorphologicUnit::unitDescription[1]:GeologicUnit::compos
ition[1]:CompositionPart::material:RockMaterial::lithology
```

The base type (MappedFeature) is not included as it is the context type. Package names are not shown to keep the path readable.

A W3C XPath equivalent (using prefixes proposed in 9.1)

```
gsmlb:Specification/gsmlb:GeomorphologicUnit/gsmlb:unitDescription[1]/gsm
lb:GeologicUnit/gsmlb:composition[1]/gsmlb:CompositionPart/gsmlb:material
/gsmlb:RockMaterial/gsmlb:lithology
```

An exact path is provided when possible (e.g., see 8.9.3.1), for instance to a property of compatible types. But there are cases where the type cannot be expressed directly in OCL.

- Part of the model, such as classifiers with `<<CodeList>>` don't have specific model. XML implement them as external references (xlink:href), other encoding might implement them otherwise.
- Any property modelled as part as metadata (`MD_Metadata`) as there are no explicit requirements on how GML `metaDataProperty` should be implemented.
- Some values will either come from one "representative" instance, or be an aggregation.
- Some values are not present in GeoSciML

In such cases, guidance will be provided.

8.9.2 **GeoSciML Lite views**

8.9.2.1 Geometry type

/req/gsml4-lite/geomtype	A dataset SHALL use a single geometry type (Point, Line, Polygon, etc.).

A dataset (for example, a GML document or a GeoJSON instance or an ESRI shapefile) SHALL use a single geometry type. Most GIS applications and software which render a dataset containing geometry do not expect mixed geometries.

8.9.2.2 String properties

/req/gsml4-lite/string	Properties of type "CharacterString" SHALL contain human readable text.

String properties SHALL provide information easily readable by human. The intent of string field is to display, not to query. The string properties can be translated according to the language of the user as needed while URI properties should not.

8.9.2.3 Formal Syntax

/req/gsml4-lite/formal-syntax	Syntax of text in character string properties SHOULD be formalised.

Some string properties can be constructed using formal syntax, such as comma delimited list or any other text based structure (JSON for example). Where possible, the this syntax SHOULD be formalised in a profile of this specification.

8.9.2.4 Date and Time formatting

/req/gsml4-lite/datetime	Calendar date and time SHALL be formatted according to ISO 8601.

All dates and times, excluding geological ages, shall be formatted using ISO 8601 format (YYYY-MM-DD). When a time must be specified, time zone shall be provided.

Examples:

- 2016-01-05 (simple date)
- 2016-01-05T08:40:15-05 (time expressed for time zone GMT -5)
- 2016-01-05T13:40:15Z (same as above, but expressed in UTC a.k.a Zulu)

8.9.2.5 URI

Properties which names end with “_uri” shall contain a **single** absolute URI conformant to RFC 3986.

/req/gsml4-lite/uri	Properties which name end with “_uri” SHALL contain a string conformant to URI format as specified in RFC 3986.

Properties containing a URI should, unless stated otherwise, resolve following Linked Open Data principles.

/req/gsml4-lite/resolvable-uri	Properties containing a valid URI SHOULD be dereferenceable.

Although many vocabulary terms are defined as URI, not all URIs are actually supported by a formal Linked Open Data infrastructure. URIs are just a convenient mechanism to build unique vocabulary identifiers. Note that in some situations, some “_uri” properties might require that the URI SHALL resolve to some valid content. Those cases will be explicitly stated. Some community might create a profile of this requirements class and add more constraints, such as mandatory resolution of the URI to one or more resources and impose mandatory mime-types (GeoSciML/XML or GeoSciML/GeoJSON).

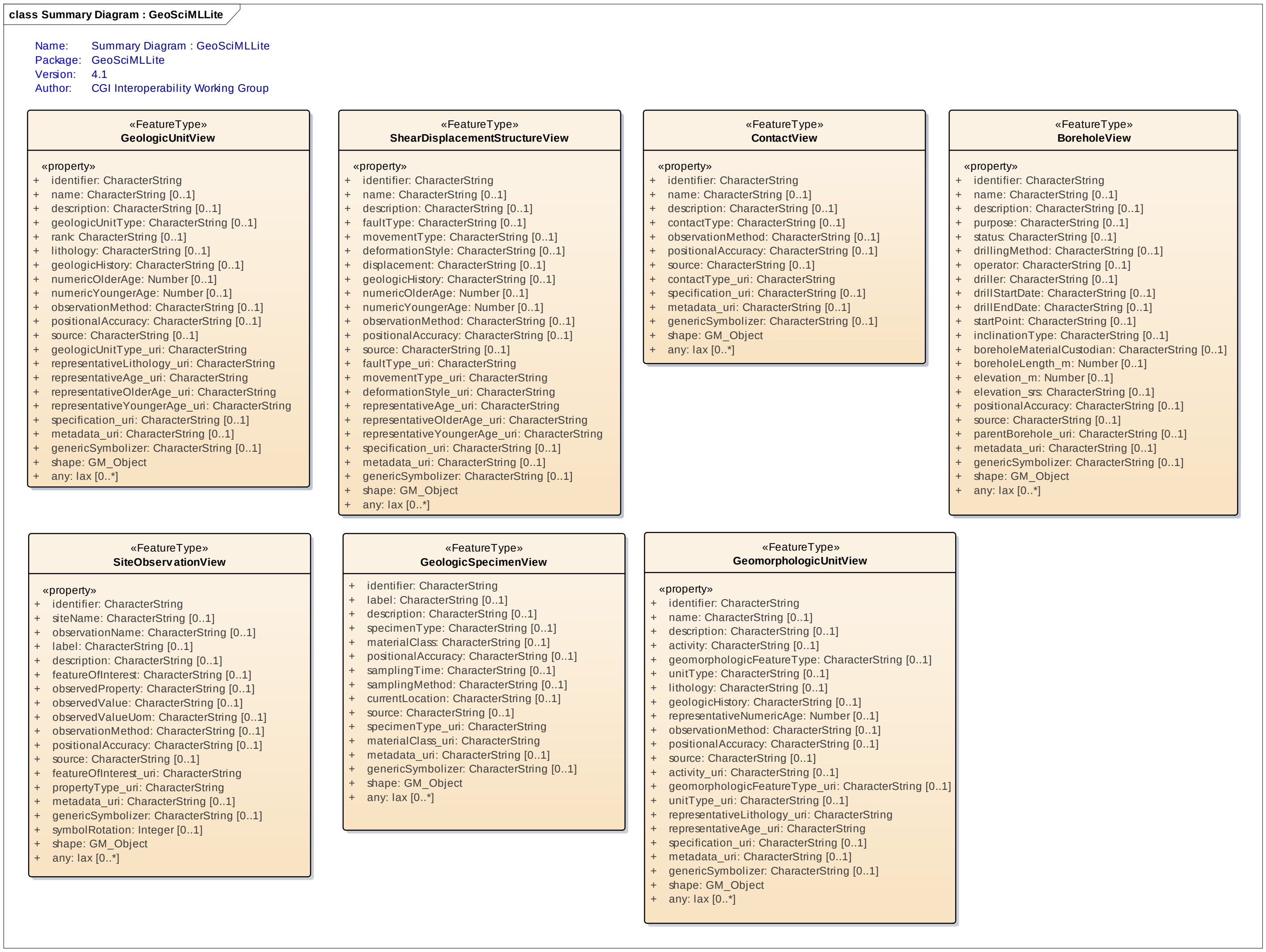


Figure 99 - GeoSciML Lite feature types.

Figure 99 shows the seven Lite feature types specified by GeoSciML 4.1. Each feature type is equivalent to a layer in a GIS or a Web Map Service.

8.9.2.6 User defined properties

/req/gsml4-lite/user-defined	Features delivered with user defined properties SHALL be conformant to GML Simple Feature Level 0.

New properties added by the data provider shall keep the feature conformant to GML Simple Feature Level 0. For example, no duplicate property names, nor extra geometry properties.

8.9.2.7 identifier

Globally unique `identifier:Primitive::CharacterString` shall uniquely identifies a tuple within the dataset.

/req/gsml4-lite/identifier-unique	Identifier SHALL be unique to a dataset.

Identifiers shall be formatted as URI according to RFC 3986. This URI could be used to access more detailed, such as a GeoSciML Basic, representation of the feature.

/req/gsml4-lite/identifier-URI	Identifiers SHALL be formatted as URI according to RFC 3986.

8.9.3 **GeologicUnitView**

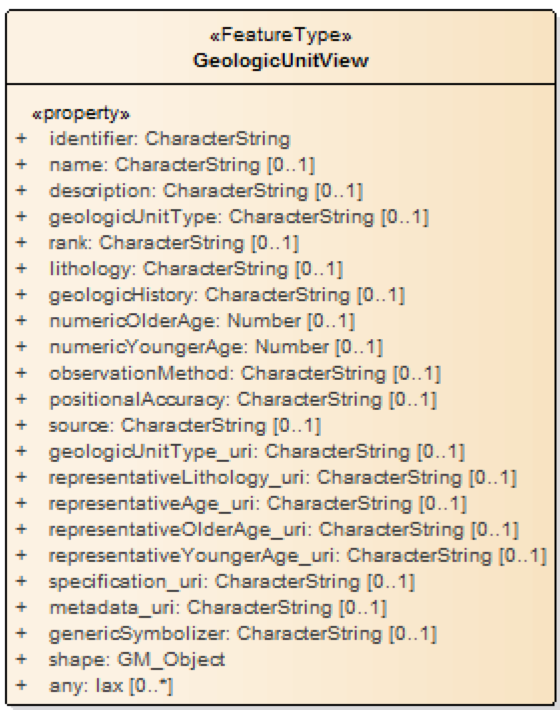


Figure 100 - GeologicUnitView feature type.

`GeologicUnitView` is a simplified view of a GeoSciML `MappedFeature` feature with key property values from an associated `GeologicUnit`. The `GeologicUnitView` property values are summarised as labels (unconstrained character strings) or arbitrarily selected classifiers to be used for thematic mapping purposes. The latter are the properties suffixed with "_uri" and will contain URIs referring to controlled concepts in published vocabularies.

8.9.3.1 Mapping

Table 9 - Mapping of GeologicUnitView properties to the GeoSciML data model.

Property	Mapping from MappedFeature
identifier	identifier
name	specification:GeologicUnit::name [1]
description	specification:GeologicUnit::description
geologicUnitType	specification:GeologicUnit::geologicUnitType [2]
rank	specification:GeologicUnit::rank [2]
lithology	specification:GeologicUnit::composition: CompositionPart::material:RockMaterial::lithology [1,2]
geologicHistory	specification:GeologicUnit::geologicHistory: GeologicEvent/description 1
numericOlderAge	specification:GeologicUnit::geologicHistory: GeologicEvent:NumericAge::olderBoundAge:Quantity::value [1]
numericYoungerAge	specification:GeologicUnit::geologicHistory: GeologicEvent:NumericAge::youngerBoundAge:Quantity::value [1]
observationMethod	specification:GeologicUnit::observationMethod:Category::value [1,2]
positionalAccuracy	positionalAccuracy:Quantity::value
source	specification:GeologicUnit::metaDataProperty(…):CI_Citation [1]
geologicUnitType_uri	specification:GeologicUnit::geologicUnitType 3
representativeLithology_uri	specification:GeologicUnit::composition: CompositionPart::material:RockMaterial::lithology [3]
representativeAge_uri	specification:GeologicUnit::geologicHistory: GeologicEvent [3]
representativeOlderAge_uri	specification:GeologicUnit::geologicHistory: GeologicEvent::youngerNamedAge [3]
representativeYoungerAge_uri	specification:GeologicUnit::geologicHistory: GeologicEvent::olderNamedAge [3]
specification_uri	specification [3]
metadata_uri	specification:GeologicUnit::metaDataProperty [3]
genericSymbolizer	
shape	shape

[1] In cases where multiple values are delivered for these elements in GeoSciML, data providers should choose one, or merge, or concatenate values into a representative single value for use in GeoSciML Lite
[2] Use an appropriate human readable label for the vocabulary
[3] Use a reference or an identifier that can be used to reach a representation.

8.9.3.2 identifier

The identifier should have the same value as the corresponding GeoSciML `MappedFeature` identifier, if available.

/req/gsml4-lite/geologicunitview-identifier	Where possible, GeologicUnitView identifier SHOULD correspond to an instance of MappedFeature.

8.9.3.3 name

If present, the property `name:Primitive::CharacterString` is a display name for the GeologicUnit.

8.9.3.4 description

If present, the property `description:Primitive::CharacterString` is a description of the `GeologicUnit`, typically taken from an entry on a geological map legend.

8.9.3.5 geologicUnitType

If present, the property `geologicUnitType` (`Primitive::CharacterString`) contains the type of `GeologicUnit` (as defined in GeoSciML). To report an identifier from a controlled vocabulary, `geologicUnitType_uri` shall be used.

8.9.3.6 rank

If present, the property `rank:Primitive::CharacterString` contain the rank of `GeologicUnit` (as defined by ISC. e.g., group, formation, member).

8.9.3.7 lithology

If present, `lithology` contains a human readable description as `Primitive::CharacterString` of the `GeologicUnit`'s lithology, possibly formatted with formal syntax (see 8.9.2.3). The description can be language-dependent. To report an identifier from a controlled vocabulary, `representativeLithology_uri` shall be used.

8.9.3.8 geologicHistory

If present, contains a human readable description in `Primitive::CharacterString`, possibly formatted with formal syntax (see 8.9.2.3), of the age of the `GeologicUnit` (where age is a sequence of events and may include process and environment information). To report an identifier from a controlled vocabulary, `representativeAge_uri`, `representativeOlderAge_uri`, `representativeYoungerAge_uri` shall be used.

8.9.3.9 numericOlderAge

If present, the property `numericOlderAge` age is a numerical representation (`Primitive::Number`) of the unit's older age in million years (Ma).

8.9.3.10 numericYoungerAge

If present, the property `numericYoungerAge` is a numerical representation (`Primitive::Number`) of the unit's younger age in million years (Ma).

8.9.3.11 observationMethod

If present, the property `observationMethod:Primitive::CharacterString` is a metadata snippet indicating how the spatial extent of the feature was determined. `ObservationMethod` is a convenience property that provides a simple approach to observation metadata when data are reported using a feature view (as opposed to observation view).

8.9.3.12 positionalAccuracy

If present, the property `positionalAccuracy:Primitive::CharacterString` is a quantitative value (a numerical value and a unit of length) defining the radius of an uncertainty buffer around a `MappedFeature` (e.g., a `positionalAccuracy` of 100 m for a line feature defines a buffer polygon of total width 200 m centred on the line).

8.9.3.13 source

If present, the property `source:Primitive::CharacterString` is human readable text describing feature-specific details and citations to source materials, and if available provides URLs to reference material and publications describing the geologic feature. This could be a short text synopsis of key information that would also be in the metadata record referenced by metadata_uri.

8.9.3.14 geologicUnitType_uri

The property `geologicUnitType_uri:Primitive::CharacterString` contains a URI referring to a controlled concept from a vocabulary defining the `GeologicUnit` types.

8.9.3.15 representativeLithology_uri

The property `representativeLithology_uri:Primitive::CharacterString` shall contain a URI referring to a controlled concept specifying the characteristic or representative lithology of the unit. This may be a concept that defines the super-type of all lithology values present within a `GeologicUnit` or a concept defining the lithology of the dominant `CompositionPart` (as defined in GeoSciML) of the unit.

/req/gsml4-lite/geologicunitview-representativeLithology	representativeLithology_uri value SHALL refer to a controlled concept specifying the characteristic or representative lithology of the unit. This may be a concept that defines the super-type of all lithology values present within a GeologicUnit or a concept defining the lithology of the dominant CompositionPart (as defined in GeoSciML) of the unit.

8.9.3.16 representativeAge_uri

The property `representativeAge_uri:Primitive::CharacterString` shall contain a URI referring to a controlled concept specifying the most representative stratigraphic age interval for the `GeologicUnit`. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising the all or part of the feature's history.

/req/gsml4-lite/geologicunitview-representativeAge	`representativeAge_uri` value SHALL refer to a controlled concept specifying the most representative stratigraphic age interval for the GeologicUnit. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising the all or part of the feature's history.

8.9.3.17 representativeOlderAge_uri

The property `representativeOlderAge_uri:Primitive::CharacterString` shall contain a URI referring to a controlled concept specifying the most representative older value in a range of stratigraphic age intervals for the `GeologicUnit`. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising the all or part of the feature's history.

/req/gsml4-lite/geologicunitview-representativeOlderAge	`representativeOlderAge_uri` value SHALL refer to a controlled concept specifying the most representative older value in a range of stratigraphic age intervals for the GeologicUnit. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising the all or part of the feature's history.

8.9.3.18 representativeYoungerAge_uri

The property `representativeYoungerAge_uri:Primitive::CharacterString` shall contain a URI referring to a controlled concept specifying the most representative younger value in a range of stratigraphic age intervals for the `GeologicUnit`. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising the all or part of the feature's history.

/req/gsml4-lite/geologicunitview-representativeYoungerAge	representativeYoungerAge_uri value SHALL refer to a controlled concept specifying the most representative younger value in a range of stratigraphic age intervals for the GeologicUnit. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising the all or part of the feature's history.

8.9.3.19 specification_uri

If present, the property specification_uri:Primitive::CharacterString shall contain a URI referring the GeoSciML GeologicUnit feature that describes the instance in detail.

/req/gsml4-lite/geologicunitview-specification	specification_uri value SHOULD refer the GeoSciML GeologicUnit feature that describes the instance in detail.

8.9.3.20 metadata_uri

If present, the property metadata_uri:Primitive::CharacterString contains a URI referring to a metadata record describing the provenance of data.

8.9.3.21 genericSymbolizer

If present, the property genericSymbolizer:CharacterString contains an identifier for a symbol from standard (locally or community defined) symbolization scheme for portrayal.

8.9.3.22 shape

The property shape:GEO::GM_Object contains a geometry defining the extent of the feature of interest.

8.9.3.23 any

A data provider may add an arbitrary number of extra properties, as long as the instance is conformant to GML Simple Feature Level 0.

8.9.4 BoreholeView

BoreholeView is a simplified view of a GeoSciML Borehole. In GeoSciML terms, this will be an instance of a Borehole feature with key property values summarised as labels (unconstrained character strings) or arbitrarily selected classifiers to be used for thematic mapping purposes. The latter are the properties suffixed with "_uri" and will contain URIs referring to controlled concepts in published vocabularies.

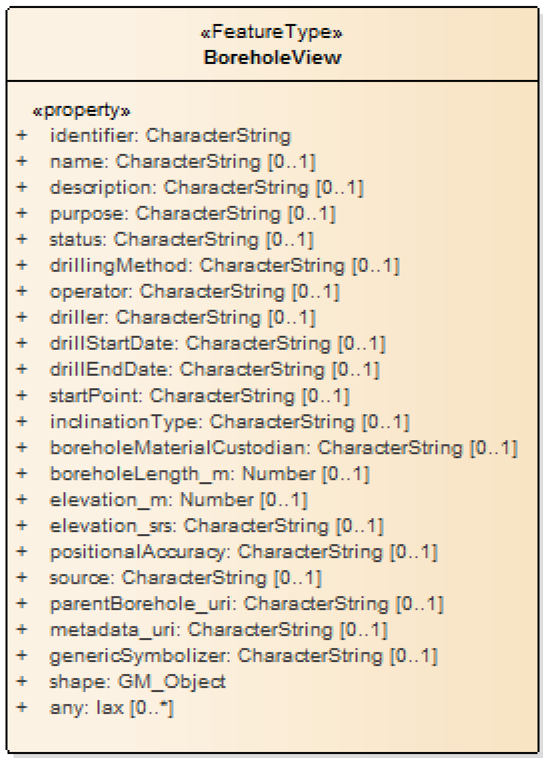


Figure 101 - BoreholeView feature type.

8.9.4.1 Mapping

Table 10 - Mapping of BoreholeView properties to the GeoSciML Borehole data model.

Property	Mapping from Borehole
identifier	identifier
Name	name [1]
description	description
purpose	indexData:BoreholeDetails::purpose [1,2]
status	
drillingMethod	downholeDrillingDetails:DrillingDetails::drillingMethod [1,2]
operator	indexData:BoreholeDetails::operator:CI_Responsibility::party:CI_Party::name
driller	indexData:BoreholeDetails::driller:CI_Responsibility::party:CI_Party::name
drillStartDate	indexData:BoreholeDetails::dateOfDrilling:TM_Period::begin:TM_Instant::position 1
drillEndDate	indexData:BoreholeDetails::dateOfDrilling:TM_Period::end:TM_Instant::position [1]

startPoint	indexData:BoreholeDetails::startPoint
inclinationType	indexData:BoreholeDetails::inclinationType [2]
boreholeMaterialCustodian	indexData:BoreholeDetails::boreholeMaterialCustodian:CI_Responsibility::party:CI_Party::name [1]
boreholeLength_m	indexData:BoreholeDetails::boreholeLength:Quantity::value
elevation_m	referenceLocation:OriginPosition::elevationDirectPosition:::coordinate
elevation_srs	referenceLocation:OriginPosition::elevation:srsName
positionalAccuracy	metaDataProperty(…):DQ_PositionalAccuracy [1]
source	metaDataProperty:(…):CI_Citation [1]
parentBorehole_uri	relatedSamplingFeature:SamplingFeatureComplex::relatedSamplingFeature:Borehole::identifier [3]
metadata_uri	metaDataProperty:MD_Metadata [3]
genericSymbolizer	
shape	shape
[1] In cases where multiple values are delivered for these elements in GeoSciML, data providers should choose one, or merge, or concatenate values into a representative single value for use in GeoSciML Lite [2] Use an appropriate human readable label for the vocabulary [3] Use a reference or an identifier that can be used to reach a representation.	

8.9.4.2 identifier

The identifier:Primitive::CharacterString property shall contain a unique identifier for this borehole and be should formatted as an absolute URI conformant to RFC 3986.

/req/gsml4-lite/boreholeview-identifier	identifier SHOULD resolve to a representation of a GeoSciML Borehole.

8.9.4.3 name

If present, the property name:Primitive::CharacterString contains a human-readable display name for the borehole.

8.9.4.4 description

If present, the property description:Primitive::CharacterString contains a human-readable description for the borehole.

8.9.4.5 purpose

If present, the purpose:Primitive::CharacterString property reports the purpose or purposes for which the borehole was drilled. (e.g., mineral exploration, hydrocarbon exploration, hydrocarbon production, groundwater monitoring, geothermal), possibly formatted with formal syntax (see 8.9.2.3).

8.9.4.6 status

If present, the property `status:Primitive::CharacterString` reports the current status of the borehole (e.g., abandoned, completed, proposed, suspended).

8.9.4.7 drillingMethod

If present, the property `drillingMethod:Primitive::CharacterString` indicates the drilling method, or methods, used for this borehole (e.g., RAB, auger, diamond core drilling, air core drilling, piston), possibly formatted with formal syntax (see 8.9.2.3).

8.9.4.8 operator

If present, the property `operator:Primitive::CharacterString` reports the organisation or agency responsible for commissioning of the borehole (as opposed to the agency which drilled the borehole).

8.9.4.9 driller

If present, the property `driller:Primitive::CharacterString` reports the organisation responsible for drilling the borehole (as opposed to commissioning the borehole).

8.9.4.10 drillStartDate

If present, the property `drillStartDate:Primitive::CharacterString` reports the date of the start of drilling formatted according to ISO8601 (e.g., 2012-03-17).

8.9.4.11 drillEndDate

If present, the property `drillEndData:Primitive::CharacterString` reports the date of the end of drilling formatted according to ISO8601 (e.g., 2012-03-28).

8.9.4.12 startPoint

If present, the property `startPoint:Primitive::CharacterString` indicates the position relative to the ground surface where the borehole commenced (e.g., open pit floor or wall, underground, natural land surface, sea floor).

8.9.4.13 inclinationType

If present, the property `inclinationType:Primitive::CharacterString` indicates the type of inclination of the borehole (e.g., vertical, inclined up, inclined down, horizontal).

8.9.4.14 boreholeMaterialCustodian

If present, the property `boreholeMaterialCustodian:Primitive::CharacterString` reports the organisation that is the custodian of the material recovered from the borehole.

8.9.4.15 boreholeLength_m

If present, the property `boreholeLength_m:Primitive::Number` reports the length of a borehole, in metres, as determined by the data provider. Length may have different sources (e.g., driller's measurement, logger's measurement, survey measurement).

8.9.4.16 elevation_m

If present, the property `elevation_m:Primitive::Number` reports the elevation data, in metres, for the borehole (i.e., wellbore) start point. This is a compromise approach to allow for delivery of legacy 2D data without elevation data, and for software that cannot process a 3D `GM_Point`.

8.9.4.17 elevation_srs

If present, the property `elevation_srs:Primitive::CharacterString` is a URI of a spatial reference system of the elevation value. (e.g., mean sea level). Mandatory if elevation_m is populated. The SRS shall be a one dimensional vertical SRS (i.e., EPSG code in the range 5600-5799).

/req/gsml4-lite/boreholeview-elevation-crs	If present, elevation_srs SHALL resolve to a valid EPSG vertical datum in the range EPSG:5600 to EPSG:5799

Example: `https://epsg.io/5711.gml`

8.9.4.18 positionalAccuracy

If present, the property `positionalAccuracy:Primitive::CharacterString` reports an estimate of the accuracy of the location of the borehole collar location. Ideally, this would be a quantitative estimate of accuracy (e.g., 20 metres).

8.9.4.19 source

If present, the `source:Primitive::CharacterString` property describes details and citations to source materials for the borehole and, if available, providing URLs to reference material and publications describing the borehole. This could be a short text synopsis of key information that would also be in the metadata record referenced by `metadata_uri`.

8.9.4.20 parentBorehole_uri

When present, the `parentBorehole_uri:Primitive::CharacterString` contains a URI referring to one or more representations of a parent borehole (e.g., a parent well of a sidetrack wellbore).

/req/gsml4-lite/boreholeview-parentBorehole-uri	If present, parentBorehole_uri SHOULD resolve to a representation of a GeoSciML borehole.

If the borehole does not have any parent, this field shall be empty.

8.9.4.21 metadata_uri

If present, the property `metadata_uri:Primitive::CharacterString` contains a URI referring to a metadata record describing the provenance of data.

8.9.4.22 genericSymbolizer

If present, the property `genericSymbolizer:Primitive::CharacterString` contains an identifier for a symbol from standard (locally or community defined) symbolization scheme for portrayal.

8.9.4.23 shape

The property `shape:GM_Object` contains a Geometry defining the extent of the borehole start point.

8.9.4.24 any

A data provider may add an arbitrary number of extra properties, as long as the instance is conformant to GML Simple Feature Level 0.

8.9.5 ContactView

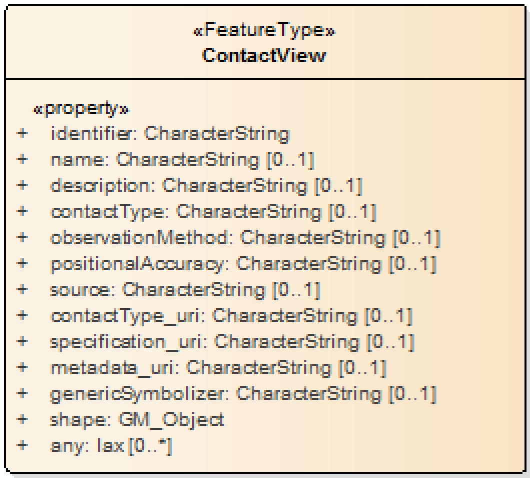


Figure 102 - ContactView feature type.

ContactView is a simplified view of a GeoSciML MappedFeature with key property values from an associated Contact feature. These properties are summarised as labels (unconstrained character strings) or arbitrarily selected classifiers to be used for thematic mapping purposes. The latter are the properties suffixed with "_uri" and will contain URIs referring to controlled concepts in published vocabularies.

8.9.5.1 Mapping

Table 11 - Mapping of ContactView properties to the GeoSciML data model.

Property	Mapping from MappedFeature
identifier	specification:Contact::identifier
name	specification:Contact::name [1]
description	specification:Contact::description
contactType	specification:Contact::contactType [2]
observationMethod	observationMethod [1,2]
positionalAccuracy	positionalAccuracy [2]
source	specification:GeologicUnit::metaDataProperty:(…):CI_Citation
contactType_uri	specification::Contact:contactType [3]
specification_uri	specification [3]
metadata_uri	specification::Contact::metaDataProperty [3]
genericSymbolizer	
Shape	shape
[1] In cases where multiple values are delivered for these elements in GeoSciML, data providers should choose one, or merge, or concatenate values into a representative single value for use in GeoSciML Lite [2] Use an appropriate human readable label for the vocabulary [3] Use a reference or an identifier that can be used to reach a representation.	

8.9.5.2 identifier

Globally unique `identifier:Primitive::CharacterString` shall uniquely identifies a tuple within the dataset and be formatted as an absolute URI conformant to RFC 3986.

/req/gsml4-lite/contactview-identifier	identifier SHOULD correspond to an instance of MappedFeature.

It should have the same value as the corresponding GeoSciML MappedFeature identifier if available.

8.9.5.3 name

If present, the property `name:Primitive::CharacterString` reports the display name for the Contact.

8.9.5.4 description

If present, the property `description:Primitive::CharacterString` reports the description of the Contact, typically taken from an entry on a geological map legend.

8.9.5.5 contactType

If present, the property `contactType:Primitive::CharacterString` reports the type of `Contact` (as defined in GeoSciML) as a human readable label. To report an identifier from a controlled vocabulary, `contactType_uri` shall be used.

8.9.5.6 observationMethod

If present, the property `observationMethod:Primitive::CharacterString` reports a metadata snippet indicating how the spatial extent of the feature was determined. `ObservationMethod` is a convenience property that provides a quick and simple approach to observation metadata when data are reported using a feature view (as opposed to observation view).

8.9.5.7 positionalAccuracy

If present, the property `positionalAccuracy:Primitive::CharacterString` reports quantitative values defining the radius of an uncertainty buffer around a `MappedFeature` (e.g., a `positionalAccuracy` of 100 m for a line feature defines a buffer polygon of total width 200 m centred on the line).

8.9.5.8 source

If present, the property `source:Primitive::CharacterString` contains a text describing feature-specific details and citations to source materials, and if available providing URLs to reference material and publications describing the contact feature. This could be a short text synopsis of key information that would also be in the metadata record referenced by `metadata_uri`.

8.9.5.9 contactType_uri

The property `contactType_uri:Primitive::CharacterString` reports a URI referring to a controlled concept from a vocabulary defining the `Contact` types.

8.9.5.10 specification_uri

If present, the property `specification_uri:Primitive::CharacterString` reports a URI referring the GeoSciML `Contact` feature that describes the instance in detail.

8.9.5.11 metadata_uri

If present, the property `metadata_uri:Primitive::CharacterString` reports a URI referring to a metadata record describing the provenance of data.

8.9.5.12 genericSymbolizer

If present, the `genericSymbolizer:Primitive::CharacterString` property contains an identifier for a symbol from standard (locally or community defined) symbolization scheme for portrayal.

8.9.5.13 shape

The property `shape:GM_Object` contains a geometry defining the extent of the contact feature.

8.9.5.14 any

A data provider can add an arbitrary number of extra properties, as long as the instance is conformant to GML Simple Feature Level 0.

8.9.6 **GeologicSpecimenView**

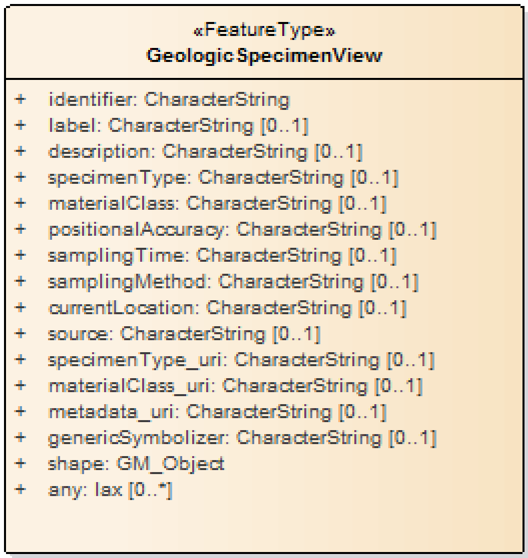


Figure 103 - GeologicSpecimenView feature type.

`GeologicSpecimenView` is a simplified view of a point-located specimen from GeoSciML `GeologicSpecimen` (an extension of Observations & Measurements - ISO19156) with key property values summarised as labels (unconstrained character strings) or arbitrarily selected classifiers to be used for thematic mapping purposes. The latter are the properties suffixed with "_uri" and will contain URIs referring to controlled concepts in published vocabularies.

8.9.6.1 Mapping

Table 12 - Mapping of GeologicSpecimenView properties to Observations and Measurements.

Property	Mapping from OM::SF_Specimen
identifier	identifier
label	name [1]
description	description
specimenType	specimenType [2]
materialClass	materialClass [2]
positionalAccuracy	metadataProperty:(…):DQ_PositionalAccuracy [1]
samplingTime	samplingTime:TM_Instant::position
samplingMethod	samplingMethod [1,2]
currentLocation	currentLocation:EX_GeographicDescription::geographicIdentifier:MD_Identifier::code
source	specification:GeologicUnit::metaDataProperty:(…):CI_Citation
specimenType_uri	specimenType [3]
materialClass_uri	materialClass [3]

metadata_uri	metadataProperty [3]
genericSymbolizer	
shape	samplingLocation

[1] **In cases where multiple values are delivered for these elements in GeoSciML, data providers should** choose **one, or merge, or concatenate values into a representative single value for use in GeoSciML Lite**
[2] **Use an appropriate** human readable label **for the vocabulary**
[3] **Use a** reference **or an identifier that can be used to reach a representation.**

8.9.6.2 identifier

Globally unique `identifier:Primitive::CharacterString` uniquely identifies a tuple within the dataset and be formatted as an absolute URI conformant to RFC 3986.

/req/gsml4-lite/geologicspecimenview-identifier	identifier SHOULD correspond to an instance of GeoSciML GeologicSpecimen.

If present, the URI should resolve to a representation that corresponds to an instance of GeoSciML GeologicSpecimen.

8.9.6.3 label

If present, the property `label:Primitive::CharacterString` contains a short label for map display. (e.g., a sample number).

8.9.6.4 description

If present, the property `description:Primitive::CharacterString` contains a detailed description of the specimen.

8.9.6.5 specimenType

If present, the property `specimentType:Primitive::CharacterString` contains a human readable description of the specimen type (e.g., hand specimen, thin section, drill core). To report an identifier from a controlled vocabulary, specimenType_uri shall be used.

8.9.6.6 materialClass

If present, the property `materialClass:Primitive::CharacterString` reports the classification of the material that comprises the specimen (e.g., rock, sediment, etc.). To report an identifier from a controlled vocabulary, `materialClass_uri` shall be used.

8.9.6.7 positionalAccuracy

If present, the property `positionalAccuracy:Primitive::CharacterString` contains a description of the positional accuracy of the sampling location. (e.g., 50 metres).

8.9.6.8 samplingTime

If present, the property `samplingTime:Primitive::CharacterString` reports a date or a date with time of when the specimen was collected formatted according to ISO 8601.

Examples:

- 2012-03-28
- 2008-02-28T14:15:23-05

8.9.6.9 samplingMethod

If present, the property `samplingMethod:Primitive::CharacterString` reports the method used to collect the specimen (e.g., diamond drilling, field mapping survey).

8.9.6.10 currentLocation

If present, the property `currentLocation:Primitive::CharacterString` reports the current location of the specimen (e.g., a warehouse or other repository location).

8.9.6.11 source

If present, the property `source:Primitive::CharacterString` reports the citation of the source of the data (e.g., a publication, map, etc.).

8.9.6.12 specimenType_uri

The property `specimentType_uri:Primitive::CharacterString` contains a URI link for a specimen type identifier from a controlled vocabulary.

8.9.6.13 materialClass_uri

The property `materialClass_uri:Primitive::CharacterString` contains a URI link for a class of material drawn from a controlled vocabulary.

8.9.6.14 metadata_uri

If present, the property `metadata_uri:Primitive::CharacterString` contains a URI link to a metadata document.

8.9.6.15 genericSymbolizer

If present, the `genericSymbolizer:Primitive::CharacterString` property contains an identifier for a symbol from standard (locally or community defined) symbolization scheme for portrayal.

8.9.6.16 shape

The property `shape:GM_Object` contains a geometry of the specimen (generally a point).

8.9.6.17 any

A data provider can add an arbitrary number of extra properties, as long as the instance is conformant to GML Simple Feature Level 0.

8.9.7 GeomorphologicUnitView

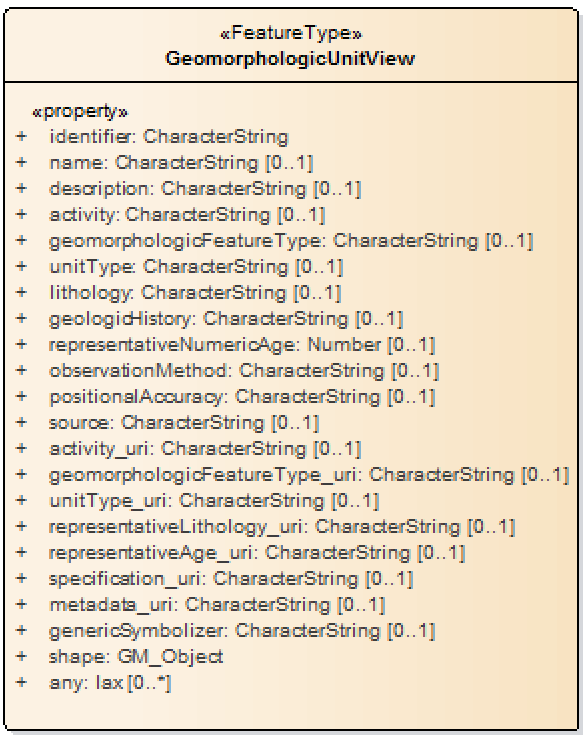


Figure 104 - GeomorphologicUnitView feature type.

`GeomorphologicUnitView` is a simplified view of a GeoSciML `GeomorphologicUnit`. In GeoSciML terms this will be in instance of a `MappedFeature` with key property values from the associated GeomorphologicUnit feature summarised as labels (unconstrained character strings) or arbitrarily selected classifiers to be used for thematic mapping purposes. The latter are the properties suffixed with "_uri" and will contain URIs referring to controlled concepts in published vocabularies.

8.9.7.1 Mapping

Table 13 - Mapping of GeomporphologicUnitView properties to GeoSciML.

Property	Mapping from GeomorphologicUnit
identifier	identifier
name	specification:NaturalGeomorphologicFeature::name [1]
description	specification:NaturalGeomorphologicFeature::description
activity	specification:NaturalGeomorphologicFeature:activity [2]
unitType	specification:NaturalGeomorphologicFeature::naturalGeomorphologicFeatureType [2] or specification:AnthropogenicGeomorphologicUnit::anthropogenicGeomorphologicFeatureType [2]
lithology	specification:GeomorphologicUnit::unitDescription:GeologicUnit::composition:CompositionPart::material:RockMaterial::lithology [1]
geologicHistory	specification:GeomorphologicUnit::unitDescription:GeologicUnit::geologicHistory:GeologicEvent::description [1]
observationMethod	specification:GeomorphologicUnit::observationMethod:Category::value [1]
positionalAccuracy	positionalAccuracy::value
source	specification:GeologicUnit::metaDataProperty:(…):CI_Citation
activity_uri	specification:NaturalGeomorphologicFeature::activity
geomorphologicFeatureType	typeOf(specification/*)::name()
geomorphologicFeatureType_uri	typeOf(specification/*)::typeName()
unitType_uri	specification:GeomorphologicUnit::geologicUnitType [3]
representativeLithology_uri	specification:GeomorphologicUnit::unitDescription:GeologicUnit::composition:CompositionPart::material:RockMaterial::lithology 3
representativeAge_uri	specification:GeomorphologicUnit::geologicHistory: GeologicEvent [3]
representativeNumericAge	specification: GeomorphologicUnit::geologicHistory: GeologicEvent:NumericAge [1]
specification_uri	specification [3]
metadata_uri	specification:GeologicUnit:metaDataProperty [3]
genericSymbolizer	
shape	shape

[1] In cases where multiple values are delivered for these elements in GeoSciML, data providers should choose one, or merge, or concatenate values into a representative single value for use in GeoSciML Lite
[2] Use an appropriate human readable label for the vocabulary
[3] Use a reference or an identifier that can be used to reach a representation.

8.9.7.2 identifier

Globally unique `identifier:Primitive::CharacterString` shall uniquely identifies a tuple within the dataset and be formatted as an absolute URI conformant to RFC 3986.

/req/gsml4-lite/geomorphologicunitview-identifier	identifier SHOULD correspond to a representation of GeoSciML MappedFeature.

If present, the URI should resolve to a representation that corresponds to an instance of GeoSciML MappedFeature.

8.9.7.3 name

If present, the property `name:Primitive::CharacterString` contains a display name for the GeomorphologicUnit.

8.9.7.4 description

If present, the property `description:Primitive::CharacterString` contains human readable text description of the GeomorphologicUnit, typically taken from an entry on a map legend.

8.9.7.5 activity

If present, the property `activity:Primitive::CharacterString` contains a human readable term to specify if the feature is changing and how fast. E.g. active, dormant, stable. To report an identifier from a controlled vocabulary, `activity_uri` shall be used.

8.9.7.6 geomorphologicFeatureType

If present, the property `geomorphologicFeatureType:Primitive::CharacterString` contains a human readable term to specify a broad classification of landform. (e.g., anthropogenic, natural). To report an identifier from a controlled vocabulary, `geomorphologicFeatureType_uri` shall be used.

8.9.7.7 unitType

If present, the property `unitType:Primitive::CharacterString` contains a human readable term for the type of `GeomorphologicUnit` (e.g., hill, crater, moraine, plain). To report an identifier from a controlled vocabulary, `unitType_uri` shall be used.

8.9.7.8 lithology

If present, the property `lithology:Primitive::CharacterString` contains a text, possibly formatted with formal syntax (see 8.9.2.3), for the description of the `GeomorphologicUnit`'s lithological composition. To report an identifier from a controlled vocabulary, `representativeLithology_uri` shall be used.

8.9.7.9 geologicHistory

If present, the property `geologicHistory:Primitive::CharacterString` contains text, possibly formatted with formal syntax (see 8.9.2.3), for the description of the age of the `GeomorphologicUnit` (where age is a sequence of events and may include process and environment information). To report identifier from a controlled vocabulary, `representativeAge_uri` shall be used.

8.9.7.10 representativeNumericAge

If present, the property `representativeNumericAge:Primitive::Number` contains a numerical value of the representative age in million years (Ma).

8.9.7.11 observationMethod

If present, the property `observationMethod:Primitive::CharacterString` contains a metadata snippet indicating how the spatial extent of the feature was determined. `ObservationMethod` is a convenience property that provides a quick approach to observation metadata when data are reported using a feature view (as opposed to observation view).

8.9.7.12 positionalAccuracy

If present, the property `positionAccuracy:Primitive::CharacterString` contains quantitative values defining the radius of an uncertainty buffer around a `MappedFeature` (e.g., a `positionalAccuracy` of 100 m for a line feature defines a buffer polygon of total width 200 m centred on the line).

8.9.7.13 source

If present, the `source:Primitive::CharacterString` property contains text describing feature-specific details and citations to source materials, and if available providing URLs to reference material and publications describing the geologic feature. This could be a short text synopsis of key information that would also be in the metadata record referenced by metadata_uri.

8.9.7.14 activity_uri

If present, the `activity_uri:Primitive::CharacterString` property reports a URI identifier of activity term drawn from a controlled vocabulary.

8.9.7.15 geomorphologicFeatureType_uri

If present, the property `geomorphologicFeatureType_uri:Primitive::CharacterString` reports a URI identifier of landform term drawn from a controlled vocabulary.

8.9.7.16 unitType_uri

If present, the property `unitType_uri:Primitive::CharacterString` reports a URI referring to a controlled concept from a vocabulary defining the `GeomorphologicUnit` types.

8.9.7.17 representativeLithology_uri

The property `representativeLithology_uri:Primitive::CharacterString` contains a URI referring to a controlled concept specifying the characteristic or representative lithology of the unit. This may be a concept that defines the super-type of all lithology values present within a `GeomorphologicUnit` or a concept defining the lithology of the dominant `CompositionPart` (as defined in GeoSciML) of the unit.

8.9.7.18 representativeAge_uri

The property `representativeAge_uri:Primitive::CharacterString` contains a URI referring to a controlled concept specifying the most representative stratigraphic age interval for the GeomorphologicUnit. This will be defined entirely at the discretion of the data provider. Typically geomorphic units are not assigned age ranges.

8.9.7.19 specification_uri

If present, the property `specification_uri:Primitive::CharacterString` contains a URI referring the GeoSciML GeomorphologicUnit feature that describes the instance in detail.

8.9.7.20 metadata_uri

If present, the property `metadata_uri:Primitive::CharacterString` contains a URI referring to a metadata record describing the provenance of data.

8.9.7.21 genericSymbolizer

If present, the property `genericSymbolizer:Primitive::CharacterString` contains an identifier for a symbol from standard (locally or community defined) symbolization scheme for portrayal.

8.9.7.22 shape

The property `shape:GM_Object` contains a geometry defining the extent of the feature of interest.

8.9.7.23 any

A data provider can add an arbitrary number of extra properties, as long as the instance is conformant to GML Simple Feature Level 0.

8.9.8 **ShearDisplacementStructureView**

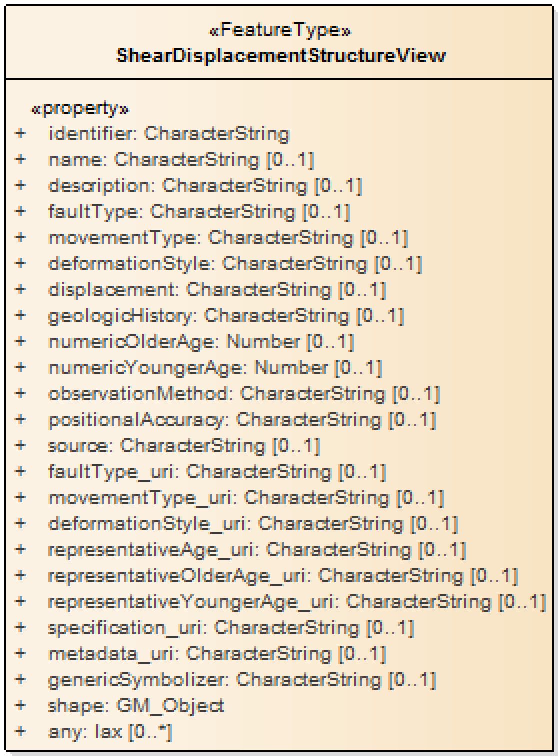


Figure 105 - ShearDisplacementStructureView feature type.

`ShearDisplacementStructureView` is a simplified view of a GeoSciML `ShearDisplacementStructure`. In GeoSciML terms this will be an instance of a `MappedFeature` with key property values from the associated `ShearDisplacementStructure` feature summarised as labels (unconstrained character strings) or arbitrarily selected classifiers to be used for thematic mapping purposes. The latter are the properties suffixed with "_uri" and will contain URIs referring to controlled concepts in published vocabularies.

8.9.8.1 Mapping

Table 14 - Mapping of ShearDisplacementStructureView properties to GeoSciML.

Property	Mapping from MappedFeature
identifier	identifier
name	specification:ShearDisplacementStructure::name [1]
description	specification:ShearDisplacementStructure::description
faultType	specification:ShearDisplacementStructure::faultType [2]
movementType	specification:ShearDisplacementStructure::stStructureDescription:DisplacementValue::movementTy

	pe [2]
deformationStyle	specification:ShearDisplacementStructure::stStructureDescription:ShearDisplacementStructureDescription::deformationStyle [2]
displacement	specification:ShearDisplacementStructure::stStructureDescription:DisplacementValue [1]
geologicHistory	specification:ShearDisplacementStructure::geologicHistory:GeologicEvent::description [1]
observationMethod	specification:ShearDisplacementStructure::observationMethod:Category::value [1]
positionalAccuracy	positionalAccuracy:Quantity::value
source	specification:GeologicUnit::metaDataProperty:(…):CI_Citation
faultType_uri	specification:ShearDisplacementStructure::faultType [3]
movementType_uri	specification:ShearDisplacementStructure::stStructureDescription:DisplacementValue::movementType [3]
deformationStyle_uri	specification:ShearDisplacementStructure::stStructureDescription:ShearDisplacementStructureDescription::deformationStyle [3]
representativeAge_uri	specification:ShearDisplacementStructure::geologicHistory:GeologicEvent [3]
representativeOlderAge_uri	specification:ShearDisplacementStructure::geologicHistory:GeologicEvent::olderNamedAge [3]
representativeYoungerAge_uri	specification:ShearDisplacementStructure::geologicHistory:GeologicEvent:youngerNamedAge [3]
numericOlderAge	specification:ShearDisplacementStructure::geologicHistory:GeologicEvent::numericAge:NumericAgeRange::olderBoundAge:Quantity::value [1]
numericYoungerAge	specification:ShearDisplacementStructure::geologicHistory:GeologicEvent::numericAge:NumericAgeRange::youngerBoundAge:Quantity::value [1]
specification_uri	specification [3]
metadata_uri	metadataProperty [3]
genericSymbolizer	
shape	shape

[1] **In case where multiple values are delivered for these elements in GeoSciML, data providers should** choose **one, or merge, or concatenate values into a representative single value for use in GeoSciML Lite**
[2] **Use an appropriate** human readable label **for the vocabulary**
[3] **Use a** reference **or an identifier that can be used to reach a representation.**

8.9.8.2 identifier

Globally unique `identifier:Primitive::CharacterString` shall uniquely identifies a tuple within the dataset and be formatted as an absolute URI conformant to RFC 3986.

/req/gsml4-lite/sheardisplacemenstructureview-identifier	identifier SHOULD correspond to a representation of GeoSciML MappedFeature.

It should have the same value as the corresponding GeoSciML MappedFeature identifier if available.

8.9.8.3 name

If present, the property `name:Primitive::CharacterString` contains a display name for the ShearDisplacementStructure.

8.9.8.4 description

If present, the property `description:Primitive::CharacterString` contains a human readable text description of the ShearDisplacementStructure, typically taken from an entry on a geological map legend.

8.9.8.5 faultType

If present, the property `faultType:Primitive::CharacterString` contains a human readable description of the type of `ShearDisplacementStructure` (as defined in GeoSciML). To report an identifier from a controlled vocabulary, faultType_uri shall be used.

8.9.8.6 movementType

If present, the property `movementType:Primitive::CharacterString` contains a human readable summary of the type of movement (e.g. dip-slip, strike-slip) on the `ShearDisplacementStructure`. To report an identifier from a controlled vocabulary, `movementType_uri` shall be used.

8.9.8.7 deformationStyle

If present, the property `deformationStyle:Primitive::CharacterString` contain a human readable description of the style of deformation (e.g. brittle, ductile etc.) for the `ShearDisplacementStructure`. To report an identifier from a controlled vocabulary, `deformationStyle_uri` shall be used.

8.9.8.8 displacement

If present, the property `displacement:Primitive::CharacterString` contains a text summarising the displacement across the `ShearDisplacementStructure`.

8.9.8.9 geologicHistory

If present, the property `geologicHistory:Primitive::CharacterString` contains a text, possibly formatted with formal syntax (see 8.9.2.3), describing the age of the ShearDisplacementStructure (where age is a sequence of events and may include process and environment information). To report identifiers from a controlled vocabulary, `representativeAge_uri, representativeOlderAge_uri and representativeYoungerAge_uri` shall be used.

8.9.8.10 numericOlderAge

If present, the property `numericOlderAge:Primitive::Number` reports the older age of the fault/shear structure, represented million years (Ma).

8.9.8.11 numericYoungerAge

If present, the property `numericYoungerAge:Primitive::Number` reports the younger age of the fault/shear structure, represented million years (Ma).

8.9.8.12 observationMethod

If present, the property `observationMethod:Primitive::CharacterString` contains a metadata snippet indicating how the spatial extent of the feature was determined. `ObservationMethod` is a convenience property that provides a quick and dirty approach to observation metadata when data are reported using a feature view (as opposed to observation view).

8.9.8.13 positionalAccuracy

If present, the property `positionAccuracy:Primitive::CharacterString` contains quantitative representation defining the radius of an uncertainty buffer around a `MappedFeature` (e.g., a `positionalAccuracy` of 100 m for a line feature defines a buffer polygon of total width 200 m centred on the line).

8.9.8.14 source

If present, the property `source:Primitive::CharacterString` contains a text describing feature-specific details and citations to source materials, and if available providing URLs to reference material and publications describing the geologic feature. This could be a short text synopsis of key information that would also be in the metadata record referenced by `metadata_uri`.

8.9.8.15 faultType_uri

The property `faultType_uri:Primitive::CharacterString` contains a URI referring to a controlled concept from a vocabulary defining the fault (`ShearDisplacementStructure`) type.

8.9.8.16 movementType_uri

The property `movementType_uri:Primitive::CharacterString` contains a URI referring to a controlled concept from a vocabulary defining the ShearDisplacementStructure movement type.

8.9.8.17 deformationStyle_uri

The property `deformationStyle_uri:Primitive::CharacterString` contains a URI referring to a controlled concept from a vocabulary defining the `ShearDisplacementStructure` deformation style.

8.9.8.18 representativeAge_uri

The property `representativeAge_uri:Primitive::CharacterString` contains a URI referring to a controlled concept specifying the most representative stratigraphic age interval for the `ShearDisplacementStructure`. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising all or part of the feature's history.

8.9.8.19 representativeOlderAge_uri

The property `representativeOlderAge_uri:Primitive:CharacterString` contains a URI referring to a controlled concept specifying the most representative lower value in a range of stratigraphic age intervals for the `ShearDisplacementStructure`. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising all or part of the feature's history.

8.9.8.20 representativeYoungerAge_uri

The property `representativeYoungerAge_uri:Primitive::CharacterString` contains a URI referring to a controlled concept specifying the most representative upper value in a range of stratigraphic age intervals for the `ShearDisplacementStructure`. This will be defined entirely at the discretion of the data provider and may be a single event selected from the geologic feature's geological history or a value summarising all or part of the feature's history.

8.9.8.21 specification_uri

If present, the property `specification_uri:Primitive::CharacterString` contains a URI referring the GeoSciML `ShearDisplacementStructure` feature that describes the instance in detail.

8.9.8.22 metadata_uri

If present, the property `metadata_uri:Primitive::CharacterString` contains a URI referring to a metadata record describing the provenance of data.

8.9.8.23 genericSymbolizer

If present, the property `genericSymbolizer:Primitive::CharacterString` contains an identifier for a symbol from standard (locally or community defined) symbolization scheme for portrayal.

8.9.8.24 shape

The property `shape:GM_Object` contains a geometry defining the extent of the feature of interest.

8.9.8.25 any

A data provider can add an arbitrary number of extra properties, as long as the instance is conformant to GML Simple Feature Level 0.

8.9.9 SiteObservationView

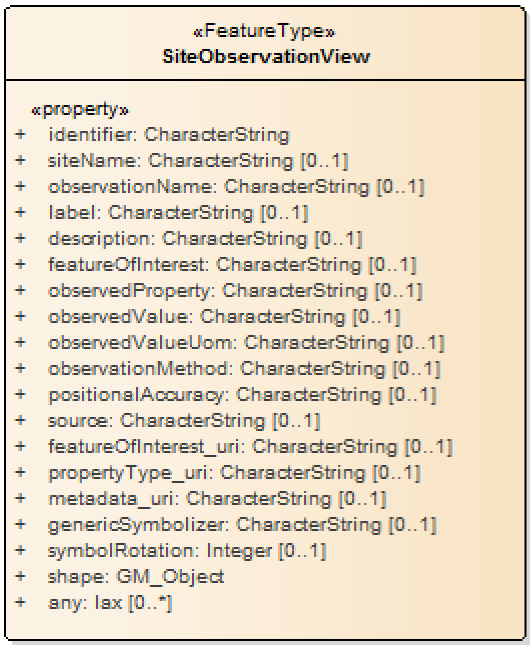


Figure 106 - SiteObservationView feature type.

`SiteObservationView` is a simplified view of a generally point-located geological observation, like a structural measurement. This is a simplified instance of a sampling geometry from Observations & Measurements (ISO19156) with an associated geological observation. Each tuple should represent a single observation. Key property values are summarised as labels (unconstrained character strings) or arbitrarily selected classifiers to be used for thematic mapping purposes. The latter are the properties suffixed with "_uri" and will contain URIs referring to controlled concepts in published vocabularies.

8.9.9.1 Mapping

Table 15 - Mapping of SiteObservationView properties to Observations & Measurements.

Property	Mapping from `OM::OM_Observation`

identifier	identifier
siteName	SF_SamplingFeature::name [1,4]
observationName	name [1]
label	name [1]
description	description
featureOfInterest	featureOfInterest:(…)::name [1]
observedProperty	observedProperty [2]
observedValue	Result [1]
observedValueUom	result [5]
observationMethod	Procedure [1]
positionalAccuracy	metadataProperty:(…):DQ_PositionalAccuracy
source	metaDataProperty:(…):CI_Citation
featureOfInterest_uri	featureOfInterest [3]
propertyType_uri	observedProperty [3]
metadata_uri	metaDataProperty [3]
genericSymbolizer	
symbolRotation	
shape	featureOfInterest:(…):GM_Object
[1] In cases where multiple values are delivered for these elements in GeoSciML, data providers should choose one, or merge, or concatenate values into a representative single value for use in GeoSciML Lite [2] Use an appropriate human readable label for the vocabulary [3] Use a reference or an identifier that can be used to reach a representation. [4] Observations associated to a SF_SamplingFeature can report it although SF_SamplingFeature::relatedObservation:OM_Observation is not traversable in reverse, unless it is also the featureOfInterest 5 OM_Measurement::value type is any type and might or might not have a unit of measurement. The property carrying depend of the result type.	

8.9.9.2 identifier

Globally unique `identifier:Primitive::CharacterString` shall uniquely identifies a tuple within the dataset and be formatted as an absolute URI conformant to RFC 3986.

/req/gsml4-lite/siteobservationview-identifier	identifier SHOULD correspond to a representation of OM::OM_Observation .

The URI should resolve to an instance of OM_Observation.

8.9.9.3 siteName

If present, the property `siteName:Primitive::CharacterString` contains the name of the sampling feature at this location (e.g. a station number, a borehole).

8.9.9.4 observationName

If present, the property `observationName:Primitive::CharacterString` contains a text identifying the observation.

8.9.9.5 label

If present, the property `label:Primitive::CharacterString` contains a short text string to associate with a symbol in a visualization/portrayal.

8.9.9.6 description

If present, the property `description:Primitive::CharacterString` contains a text string providing descriptive information about the observation.

8.9.9.7 featureOfInterest

If present, the property `featureOfInterest:Primitive::CharacterString` contains a description of the geologic feature that the observation is intended to characterize, e.g. foliation (observed property= orientation), a geologic unit (observed property = age, magnetic susceptibility, density, uranium content). The property is equivalent to O&M `OM_Observation::featureOfInterest`. To report a URI of the feature of interest, `featureOfInterest_uri` shall be used.

8.9.9.8 observedProperty

If present, the property `observedProperty:Primitive::CharacterString` contains a description of the property reported in this record. (E.g. orientation, age, density, gold content) as a human readable text. To report an identifier of the observedProperty from a controlled vocabulary, `propertyType_uri` shall be used.

8.9.9.9 observedValue

If present, the property `observedValue:Primitive::CharacterString` contains the result of the observation. This field is implemented as a character string to allow reporting various type of values, the value may be numeric (e.g., 235) or textual (e.g., red). Units of measure shall be reported in `observedValueUom`.

8.9.9.10 observedValueUom

If relevant, the property `observedValueUom:Primitive::CharacterString` contains the unit of measure for a numerical value of an observation or measurement, preferably from a controlled vocabulary.

8.9.9.11 observationMethod

If present, the `observationMethod:Primitive::CharacterString` property contains a method description, preferably a term from a controlled vocabulary, to categorize the observation method. Further details on procedure can be put in the source field.

8.9.9.12 positionalAccuracy

If present, the property `positionalAccuracy:Primitive::CharacterString` provides an estimate of the position uncertainty for the site location. For numerical measurements, include a unit of measure in the description. (e.g., 50 metres, poor, good).

8.9.9.13 source

If present, the property `source:Primitive::CharacterString` contains a text description of measurement procedure, processing, and provenance of data.

8.9.9.14 featureOfInterest_uri

The property `featureOfInterest:Primitive::CharacterString` is functionally equivalent to `OM_Observation::featureOfInterest` of IS19156. It contains a URI link to a representation of the feature of interest (e.g., a GeoSciML geologic unit or structure).

8.9.9.15 propertyType_uri

The property `propertyType_uri:Primitive:CharacterString` is functionally equivalent to `OM_Observation::observedProperty`. It contains a URI to a term from a controlled vocabulary of observed property types.

A property type shall identify a "*phenomenon associated with the feature-of-interest.*" (OGC 10-004r3, clause 7.2.2.8). The Observations and Measurements specification (op. cit.) explains that a property type "*may be, but need not be, modelled as a property (in the sense of the General Feature Model) in a formal application schema that defines the type of the feature-of-interest*" or "*Property-type definitions may be organized into a hierarchy or ontology and managed in a register and catalogued to support discovery functions.*"

8.9.9.16 metadata_uri

If present, the property `metadata_uri:Primitive::CharacterString` contains a URI link to metadata document.

8.9.9.17 genericSymbolizer

If present, the property `genericSymbolizer:Primitive::CharacterString` contains an identifier for a symbol to portray this observation. Conventions for symbol identifiers can be adopted within information exchange communities.

8.9.9.18 symbolRotation

If present, the `symbolRotation:Integer` property contains an integer value between 0 and 359 to specify rotation of symbol at this location, e.g. rotation of a geologic strike and dip symbol to reflect the strike azimuth. The angular convention shall be geographic angle (clockwise with 0 at geographic north pole, therefore 90 degree is east).

/req/gsml4-lite/siteobservationview-symbolRotation	If present, the symbolRotation SHALL be a value in the range [0,360[.

8.9.9.19 shape

The property `shape:GM_Object` contains the geometry of the observation site.

8.9.9.20 any

A data provider can add an arbitrary number of extra properties, as long as the instance is conformant to GML Simple Feature Level 0.

9. XML Encoding Requirement classes (Normative)

XSD schemas were derived from the UML model following GML 3.3 encoding (OGC ISO19136-2, OGC 10-129r1) that extends and supersedes some of ISO 19136-2007, specifically clauses 11 (CodeType encoding) and 12.3 (Association encoding)

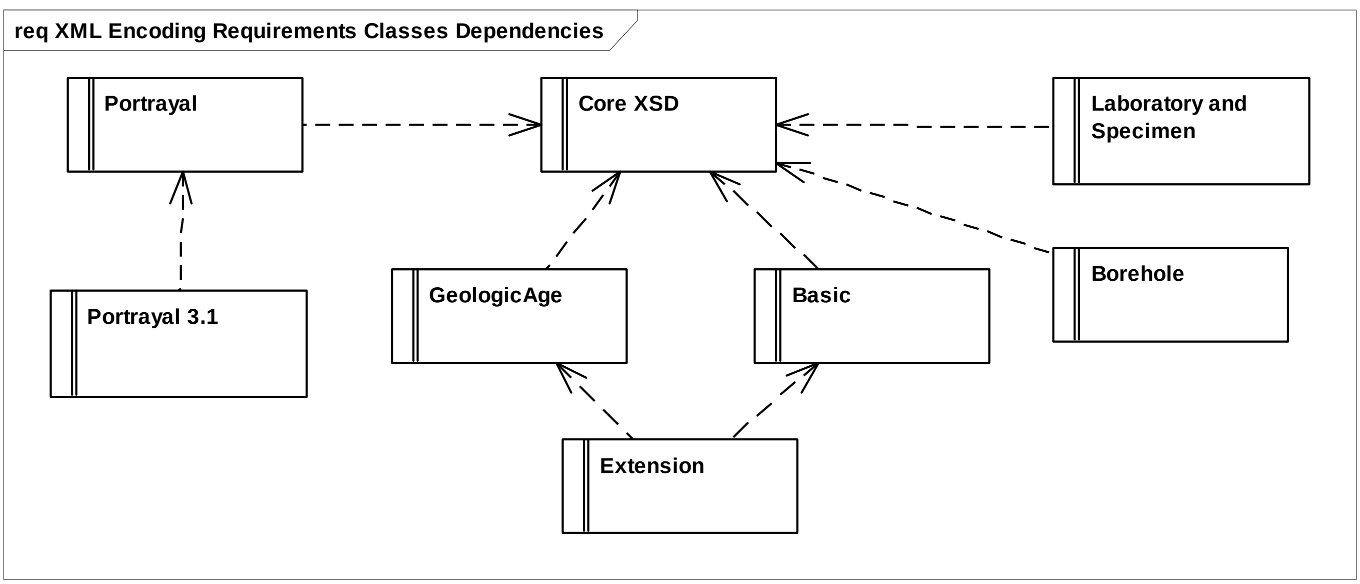


Figure 107 - XML Encoding requirements classes dependencies (external dependencies not show)

The normative artefacts for XML encoding are the W3C XSD documents and W3C schematron SCH documents provided online with this specification. Those documents explicitly provide the requirements that must be met by any XML instance claiming compliance to this specification. Any requirements that cannot be expressed in XSD or SCH are described in the relevant XML encoding section of this document. Therefore, compliant XML instances shall

1) validate with XSD schemas,

2) pass schematron rules and then

3) pass compliance tests listed in relevant compliance sections.

9.1 Prefixes used in examples

For brevity in XML examples, namespace declarations might be omitted. Throughout this document, the following namespace mappings will be assumed:

Table 16 : Default prefix mapping for xml snippets

Prefix	Namespace URI
cit	http://standards.iso.org/iso/19115/-3/cit/1.0
cv	http://www.opengis.net/cv/0.2/gml32
gco	http://www.isotc211.org/2005/gco
gmd	http://www.isotc211.org/2005/gmd
gml	http://www.opengis.net/gml/3.2
gmlr	http://www.opengis.net/gml/3.3/lr
gmlexr	http://www.opengis.net/gml/3.3/exr
gsmlb	http://www.opengis.net/gsml/4.1/GeoSciML-Basic
gsmlbh	http://www.opengis.net/gsml/4.1/Borehole
gsmle	http://www.opengis.net/gsml/4.1/GeoSciML-Extension
gsmlgt	http://www.opengis.net/gsml/4.1/GeologicTime
gsmlla	http://www.opengis.net/gsml/4.1/LaboratoryAnalysis-Specimen
gsmlp	http://www.opengis.net/gsml/4.1/Geosciml-Lite
mrl	http://standards.iso.org/iso/19115/-3/mrl/1.0
om	http://www.opengis.net/om/2.0
sam	http://www.opengis.net/sampling/2.0
sams	http://www.opengis.net/samplingSpatial/2.0
spec	http://www.opengis.net/samplingSpecimen/2.0
swe	http://www.opengis.net/swe/2.0
wfs	http://www.opengis.net/wfs/2.0
xlink	http://www.w3.org/1999/xlink

Also to improve readability, the following XML entities are used in instance examples.

```
<!ENTITY guid "http://www.ietf.org/rfc/rfc2616">

<!ENTITY resource " http://resource.geosciml.org">

<!ENTITY nil "http://www.opengis.net/def/nil/OGC/0/unknown">

]>
```

9.2 GeoSciML Core XML Abstract Requirements Class (Normative)

Abstract Requirements Class	
/req/gsml4xsd	
Target type	Data instance
Dependency	/req/gsml4-core
Dependency	W3C XML Schema Definition Language 1.1
Dependency	ISO19118 Encoding
Dependency	ISO 19136:2007 Geography Markup Language (GML)
Dependency	ISO19136-2:2015 Geography Markup Language (GML) Part 2: Extended schemas and encoding rules
Dependency	OMXML http://www.opengis.net/doc/IS/OMXML/2.0
Dependency	SWE Common 2.0 08-094r1 Clause 8
Dependency	ISO19115-3 encoding (preliminary)
Requirement	**/req/gsml4xsd/xsd** An XML instance SHALL validate against XSD schema.
Requirement	**/req/gsml4xsd/sch** An XML instance SHALL pass schematron rules.
Requirement	**/req/gsml4xsd/codelist** Vocabulary term SHALL be encoded with HTTP URI in `@xlink:href` and provide a human readable description in `@xlink:title`.
Recommendation	**/req/gsml4xsd/identifier-uri** Feature identifiers (unique name) provided in gml:identifier and @codeSpace = "http://www.ietf.org/rfc/rfc2616" SHOULD be URI of resource using Linked Open Data principles.
Recommendation	**/req/gsml4xsd/iso8601-time** All date-time elements occurrences SHOULD be encoded using ISO8601 extended time format.
Requirement	**/req/gsml4xsd/time-zone** The value of each time element SHALL include a time zone definition using a signed 4 digit character or a 'Z' to represent Zulu or Greenwich Mean Time (GMT). This is defined by the following regular expression: (Z|[+-]HH:MM)..

This requirements class is shared by all GML/XML GeoSciML instances.

9.2.1 XML document validation

An XML instance shall validate to both the XSD and schematron rules provided by this specification for each of the XML requirements classes.

/req/gsml4xsd/xsd	An XML instance SHALL validate against XSD schema.

/req/gsml4xsd/sch	An XML instance SHALL pass schematron rules.

9.2.2 **CodeList**

Open code lists (see 8.2.7) are encoded as `gml:ReferenceType` which is a sequence of `gml:OwnershipAttributeGroup` and `gml:AssociationAttributeGroup`, providing a series of xml attributes from W3C XLINK (http://www.w3.org/TR/xlink11/). A vocabulary term reference has mandatory `xlink:href` and `xlink:title` attributes.

```
<gsmlb:lithology link:href="http://resource.geosciml.org/
classifier/cgi/lithology/granite" xlink:title="granite"/>
```

The `xlink:href` contains an absolute HTTP URI that should resolve to a resource representation (often a SKOS document). The resource can have multiple representations and it is not guaranteed that an XML parsable document can be obtained from the vocabulary service.

/req/gsml4xsd/codelist	Vocabulary term SHALL be encoded with HTTP URI in xlink:href and provide a human readable description in xlink:title.

9.2.3 **Identifiers**

The GeoSciML community has developed a best practice of using http://www.ietf.org/rfc/rfc2616 as a codespace for string with authority to designate string that are resolvable HTTP URI.

`gml:identifier`'s flagged with the specific codeSpace "`http://www.ietf.org/rfc/rfc2616`" should be resolvable HTTP URI that return an instance of itself.

/req/gsml4xsd/identifier-uri	Feature identifiers (unique name) provided in `gml:identifier` and `@codeSpace` = "`http://www.ietf.org/rfc/rfc2616`" SHOULD be URI of resource using Linked Open Data principles.

```
<gml:identifier codeSpace="
http://www.ietf.org/rfc/rfc2616/">http://data.geoscience.gov.x
x/feature/asc/geologicunit/stratno/25947</gml:identifier>
```

Resolving http://data.geoscience.gov.xx/feature/asc/geologicunit/stratno/25947 shall return:

```
<gsmlb:GeologicUnit gml:id="G1">
```

```
(…)
<gml:identifier codeSpace="
http://www.ietf.org/rfc/rfc2616/">http://data.geoscience.gov.x
x/feature/asc/geologicunit/stratno/25947</gml:identifier>
(…)
</gsmlb:GeologicUnit>
```

9.2.4 Nillables or Voidables

A nillable property (identified as "voidable" in the UML model) is a property than can document the reason that a value is not provided.. There are two ways to identify a nil value.

- Using XSD xsi:nil="true" and nilReason. Where available, this encoding method should be used to indicate nilled property values.
- Using a HTTP URI identifier defined by a community as representing a null value. OGC uses `http://www.opengis.net/def/nil/OGC/0/{nilReason}` (OGC 12-110).

9.2.5 Date encoding

The date-time values shall conform to ISO 8601 standards. Although this is already a GML 3.2 encoding rule (clause 14.2.2.7), this format should also be used in any string that should contain a date, or date and time.

/req/gsml4xsd/iso8601-time	All date-time occurrences SHOULD be encoded using ISO8601 extended time format.

Note that this precludes the use of time-coordinate systems such as UNIX time. This is specified in order to be maximally consistent with TimeSeriesML requirements.

The time zone shall be included in the time element.

/req/gsml4xsd/time-zone	The value of each time element SHALL include a time zone definition using a signed 4 digit character or a 'Z' to represent Zulu or Greenwich Mean Time (GMT). This is defined by the following regular expression: (Z|[+-]HH:MM).

Greenwich Mean Time (GMT or Zulu)

```
<om:phenomenonTime>
  <gml:TimeInstant gml:id="ti.1">
        <gml:timePosition>1981-09-12T00:00:00Z</gml:timePosition>
  </gml:TimeInstant>
</om:phenomenonTime>
```

Time Zone (example is Newfoundland time zone -3:30)

```
<om:phenomenonTime>
  <gml:TimeInstant gml:id="ti.2">
         <gml:timePosition>1981-09-12T00:00:00-03:30</gml:timePosition>
  </gml:TimeInstant>
</om:phenomenonTime>
```

9.3 GeoSciML Basic XML Requirements Class (Normative)

Requirements Class	
/req/gsml4xsd-basic	
Target type	Data instance
Dependency	/req/gsml4-basic
Dependency	/req/gsml4xsd-core
Requirement	**/req/gsml4xsd-basic/xsd** An XML instance document shall validate with schema located at http://schemas.opengis.net/gsml/4.1/geoSciMLBasic.xsd
Requirement	**/req/gsml4xsd-basic/sch** An XML instance document shall pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/geoSciMLBasic.sch.

All the elements from the basic package must be schema valid according to the XSD document provided at http://schemas.opengis.net/gsml/4.1/geoSciMLBasic.xsd

/req/gsml4xsd-basic/xsd	An XML instance document SHALL validate with schema located at http://schemas.opengis.net/gsml/4.1/geoSciMLBasic.xsd.

All the elements from basic package must pass the schematron rules defined in the schematron file located at http://schemas.opengis.net/gsml/4.1/geoSciMLBasic.sch.

/req/gsml4xsd-basic/sch	An XML instance document SHALL pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/geoSciMLBasic.sc h.

Some properties links to stub property blocks (see 5.1) whose values are empty abstract classes in the GeoSciML Basic package. Since abstract description classes are DataType, the property is inline only and therefore an empty property is not schema valid.

This instance is **not** XSD valid:

```
<?xml version="1.0" encoding="UTF-8"?>
<GeologicUnit xmlns="http://www.opengis.net/gsml/4.1/GeoSciML-
Basic" xmlns:gml="http://www.opengis.net/gml/3.2" gml:id="x1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://xmlns.geosciml.org/GeoSciML-Basic/4.1
http://schemas.geosciml.org/geosciml/4.1/geoSciMLBasic.xsd">
...
   <gbMaterialDescription></gbMaterialDescription>
...
</GeologicUnit>
```

9.3.1 relatedFeature

In GeoSciML Basic, relatedFeature is byReference only. AbstractFeatureRelation subtypes are materialized in Extension package.

9.4 GeoSciML Extension XML Requirements Class (Normative)

Requirements Class	
/req/gsml4xsd-extension	
Target type	Data instance
Dependency	/req/gsml4-extension
Dependency	/req/gsml4xsd-basic
Dependency	/req/gsml4xsd-geologictime
Requirement	**/req/gsml4xsd-extension/xsd** An XML instance document SHALL validate with schema located at http://schemas.opengis.net/gsml/4.1/ geoSciMLExtension.xsd.
Requirement	**/req/gsml4xsd-extension/sch** An XML instance document SHALL pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/geoSciMLExtension.sch.

All the elements from the GeoSciML Extension package must be schema valid according to the XSD document provided at http://schemas.opengis.net/gsml/4.1/geoSciMLExtension.xsd.

/req/gsml4xsd-extension/xsd	An XML instance document SHALL validate with schema located at http://schemas.opengis.net/gsml/4.1/ geoSciMLExtension.xsd.

All the elements from the GeoSciML Extension package must pass the schematron rules defined in the schematron file located at http://schemas.opengis.net/gsml/4.1/geoSciMLExtension.sch.

/req/gsml4xsd-extension/sch	An XML instance document SHALL pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/geoSciMLExtension.sch.

9.5 GeoSciML GeologicTime XML Requirements Class (Normative)

Requirements Class	
/req/gsml4xsd-geologictime	
Target type	Data instance
Dependency	/req/gsml4-geologictime
Dependency	/req/gsml4xsd-core
Requirement	**/req/gsml4xsd-geologictime/xsd** An XML instance document SHALL validate with schema located at http://schemas.opengis.net/gsml/4.1/geologicTime.xsd
Requirement	**/req/gsml4xsd-geologictime/sch** An XML instance document SHALL pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/geologicTime.sch

All the elements from the GeoSciML Geologic Time package must be schema valid according to the XSD document provided at http://schemas.opengis.net/gsml/4.1/geologicTime.xsd.

/req/gsml4xsd-geologictime/xsd	An XML instance document SHALL validate with schema located at http://schemas.opengis.net/gsml/4.1/geologicTime.xsd.

All the elements from the GeoSciML Geologic Time package must pass the schematron rules defined in the schematron file located at http://schemas.opengis.net/gsml/4.1/geologictime.sch.

/req/gsml4xsd-geologictime/sch	An XML instance document SHALL pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/geologicTime.sch.

9.6 GeoSciML Borehole XML Requirements Class (Normative)

Requirements Class	
/req/gsml4xsd-borehole	
Target type	Data instance
Dependency	/req/gsml4-borehole
Dependency	/req/gsml4xsd-core
Requirement	**/req/gsml4xsd-borehole/xsd** An XML instance document shall validate with schema located at

	http://schemas.opengis.net/gsml/4.1/borehole.xsd
Requirement	**/req/gsml4xsd-borehole/sch** An XML instance document shall pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/borehole.sch

All the elements from the Borehole package must be schema valid according to the XSD document provided at http://schemas.opengis.net/gsml/4.1/borehole.xsd.

/req/gsml4xsd-borehole/xsd	An XML instance document shall validate with schema located at http://schemas.opengis.net/gsml/4.1/borehole.xsd.

All the elements from the Borehole package must pass the schematron rule defined in the schematron file located at http://schemas.opengis.net/gsml/4.1/borehole.sch.

/req/gsml4xsd-borehole/sch	An XML instance document shall pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/borehole.sch.

9.7 GeoSciML LaboratoryAnalysis-Specimen XML Requirements Class (Normative)

Requirements Class	
/req/gsml4xsd-lab	
Target type	Data instance
Dependency	/req/gsml4-lab
Dependency	/req/gsml4xsd-core
Requirement	**/req/gsml4xsd-lab/xsd** An XML instance document SHALL validate with schema located at http://schemas.opengis.net/gsml/4.1/laboratoryAnalysis-Specimen.xsd
Requirement	**/req/gsml4xsd-lab/sch** An XML instance document SHALL pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/laboratoryAnalysis-Specimen.sch

All the elements from the GeoSciML Laboratory Analysis & Specimen package must be schema valid according to the XSD document provided at http://schemas.opengis.net/gsml/4.1/laboratoryAnalysis-Specimen.xsd.

/req/gsml4xsd-lab/xsd	An XML instance document SHALL validate with schema located at http://schemas.opengis.net/gsml/4.1/laboratoryAnalysis-Specimen.xsd.

All the elements from the GeoSciML Laboratory Analysis & Specimen package must pass the schematron rule defined in the schematron file located at http://schemas.opengis.net/gsml/4.1/laboratoryAnalysis-Specimen.sch.

/req/gsml4xsd-lab/sch	XML instance document SHALL pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/laboratoryAnalysis-Specimen.sch.

9.8 Abstract GeoSciML Lite XML Requirements Class (Normative)

Abstract Requirements Class	
/req/gsml4xsd-lite	
Target type	Data instance
Dependency	/req/gsml4-lite
Dependency	/req/gsml4xsd
Dependency	GML Simple Feature OGC 10-100r3 SF-0
Requirement	**/req/gsml4xsd-lite/SF-0** An XML instance document SHALL be compliant to GML Simple Feature Level 0.
Recommendation	**/req/gsml4xsd-lite/SF-0-simpletype** User defined elements SHOULD be XSD simpleType.
Recommendation	**/req/gsml4xsd-lite/user-xsd** An XSD schema SHOULD be provided by data provider to validate user defined properties.
Recommendation	**/req/gsml4xsd-lite/user-ns** User properties SHOULD be defined in a namespace unique to a community or a data provider.

The abstract GeoSciML Lite encoding sets general encoding rules for XML targets, regardless of version of GML.

9.8.1 Simple Feature

GeoSciML Lite schemas are meant to deliver simple content, consistent with simple scenarios described in GML Simple Feature Level 0 (OGC 10-100r3). User defined properties must respect the same constrains as defined in SF-0 specification.

/req/gsml4xsd-lite/SF-0	An XML instance document SHALL be compliant to GML Simple Feature Level 0.

Simple Feature defines 3 compliance levels summarized in Table17.

Table 17 - Reproduction of Table 1 of 10-100r3 (Clause 2.1).

	Level SF-0	Level SF-1	Level SF-2
restricted set of built-in nonspatial property types	Yes[1]	Yes[1]	No
Restricted set of property-types	Yes[2]	Yes[2]	Yes[2]
user-defined property types	No	Yes	Yes
use of nillable and xsi:nil	No	Yes	Yes
cardinality of properties	0..1	0..unbounded	0..unbounded
non-spatial property values references	Yes[3]	Yes[3]	Yes
spatial property values references	Yes[3]	Yes[3]	Yes

1. string, integer, measurement, date, real, binary, boolean, URI
2. Point, Curve (LineString), Surface (Polygon), Geometry, MultiPoint, MultiCurve, MultiSurface, MultiGeometry
3. In levels 0 and 1, remote values for properties are supported **only** through the use of the type gml:ReferenceType. The more generalized GML property-type pattern allowing mixed inline and byReference encoded property values within the same instance document is disallowed.

9.8.2 Simple Content

SF-0 allows the definition of complex content (Clause 9.3.2 of OGC 10-100r3). To be consistent with the most common scenario encountered in GIS which is a direct mapping from a database table to XML, this specification recommends that user defined content be restricted to simple type.

/req/gsml4xsd-lite/SF-0-simpletype	User defined elements SHOULD be XSD simpleType.

GeoSciML Lite allows user defined properties to be appended at the end of the list of feature properties using xsd:any

```
<any processContents="lax" minOccurs="0" maxOccurs="unbounded">
       <annotation>
              <documentation>A placeholder allowing any user-defined
attributes to be delivered in addition to those specified
above.</documentation>
       </annotation>
</any>
```

Process content is set to “lax”, which means the validator will attempt to validate user defined property only if a schema is. To help client applications and developers to validate instance containing user defined properties, a XSD schema should be provided in the instance's schemaLocation attribute.

/req/gsml4xsd-lite/user-xsd	An XSD schema SHOULD be provided by data provider to validate user defined properties.

9.8.3 **User Defined Namespaces**

This specification does not prescribe if the user types are to be defined in GeoSciML Lite namespace or using a different namespace. It is understood that this might be constrained by the technology used to generate the instance. But to avoid potential conflict with future minor changes to GeoSciML Lite, or name conflicts when aggregating results from many sources, it is recommended that the data providers, or the community, use different namespaces, if possible.

/req/gsml4xsd-lite/user-ns	User properties SHOULD be defined in a namespace unique to a community or a data provider.

9.9 GeoSciML Lite GML 3.1 profile (Normative)

Requirements Class	
/req/gsml4xsd-lite-31	
Target type	Data instance
Dependency	/req/gsml4-lite
Dependency	/req/gsml4xsd-lite
Requirement	**/req/gsml4xsd-lite-31/xsd** An XML instance document shall validate with schema located at http://schemas.opengis.net/gsml/4.1/geosciml-lite.xsd.
Requirement	**/req/gsml4xsd-lite-31/sch** An XML instance document shall pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/geosciml-lite.sch.

Because of the limited availability of WFS 2.0 compliant servers and clients, GeoSciML SWG officially supports WFS 1.1.0 and GML 3.1.1 for delivery of Lite features.

All the elements from the GeoSciML Lite package must be schema valid according to the XSD document provided at http://schemas.opengis.net/gsml/4.1/geosciml-lite.xsd.

/req/gsml4xsd-lite-31/xsd	An XML instance document shall validate with schema located at http://schemas.opengis.net/gsml/4.1/geosciml-portrayal.xsd.

All the elements from the GeoSciML Lite package must pass the schematron rules defined in the schematron file located at http://schemas.opengis.net/gsml/4.1/geosciml-lite.sch.

/req/gsml4xsd-lite-31/sch	An XML instance document shall pass schematron rules defined in schematron file located at http://schemas.opengis.net/gsml/4.1/geosciml-lite.sch.

10. Media Types for any data encoding(s)

GeoSciML 4.1 data conforming to clause 8 is encoded in GML-conformant XML documents. The standard MIME-type and sub-type for GML data should be used to indicate the encoding in internet exchange, as specified in *MIME Media Types for GML*, namely

```
application/gml+xml
```

11. Abbreviations and Acronyms

EarthResourceML	Earth Resource Markup Language (www.earthresourceml.org)
INSPIRE	The INSPIRE Directive of the European Union was begun in May 2007 to establish an infrastructure for spatial information in Europe to support Community environmental policies (http://inspire.ec.europa.eu/)
IUGS	International Union of Geological Sciences (www.iugs.org)
IUGS CGI	International Union of Geological Sciences, Commission for the Management and Application of Geoscience Information (www.cgi-iugs.org)
GeoSciML	Geoscience Markup Language (www.geosciml.org)
GWML	GroundWater Markup Language
RDBMS	Relational database management system
UCUM	Unified Code for Units of Measure (http://unitsofmeasure.org/ucum.html)

Annexes

Annex A. Conformance classes

A.1. Conformance class: GeoSciML Conceptual

Conformance Class	**/conf/gsml4-conceptual**	
Requirements	req/gsml4-conceptual	
Test	/conf/**gsml4-conceptual/similarity**	
	Requirement	**/req/gsml4-conceptual/similarity**
	Test purpose	Ensure that the target logical model is compatible with the conceptual model.
	Test method	Determine semantic similarity between the logical model and conceptual model using an established method such as : (i) visual comparison of the UML diagrams, (ii) comparison of logical and conceptual components expressed in a common knowledge representation language such as first order logic, or (iii) comparison after mapping to a reference ontology.
	Test type	Capability

A.2. Conformance class: GeoSciML Core Abstract

Conformance Class	/conf/gsml4-core	
Requirements	/req/gsml4-core	
Dependency	Urn:iso:dis:iso:19156:clause:A.1.1	
Dependency	RFC 3986	
Test	**/conf/gsml4-core/uml-entity-name**	
	Requirement	/req/gsml4-core/uml-entity-name
	Test purpose	Ensure that the names used in the target implementation matches the names in the logical model
	Test method	Visual inspection that, when possible, name used in the target implementation matches the names in the logical model.
	Test type	
Test	**/conf/gsml4-core/uml-cardinality**	

	Requirement	/req/gsml4-core/uml-cardinality
	Test purpose	Ensure that the cardinalities of the properties are the same as the logical model
	Test method	Visually inspect the target implementation and validate that all properties have the same cardinality as the one expressed in the logical model.
	Test type	
Test	**/conf/gsml4-core/uml-abstract**	
	Requirement	/req/gsml4-core/uml-abstract
	Test purpose	Ensure that target implementation does not allow materialisation of abstract classes
	Test method	Visually inspect the target implementation and validate that no classifiers (Feature, Type or Datatype) marked as abstract can be materialised.
	Test type	Capability
Test	**/conf/gsml4-core/uml-polymorphism**	
	Requirement	/req/gsml4-core/uml-polymorphism
	Test purpose	Ensure that target implementation has mechanisms to allow type substitutions for property values.
	Test method	Visually check the target implementation accept all substitutable types for property values
	Test type	Capability
Test	**/conf/gsml4-core/quantities-uom**	
	Requirement	/req/gsml4-core/quantities-uom
	Test purpose	Ensure that quantities have a governed units of measure
	Test method	Visually check that the target implementation has a mechanism to enforce a unit of measure from a governed source.
	Test type	Capability
Test	**/conf/gsml4-core/codelist**	
	Requirement	/req/gsml4-core/codelist
	Test purpose	Ensure that vocabulary terms are encode as URI according to RFC3986
	Test method	Visually check that the target implementation has a mechanism to enforce a unit of measure from a governed source.
	Test type	Capability

A.3. Conformance class: GeoSciML Linked Open Data

Conformance Class	/conf/gsml4-core	
Requirements	/req/gsml4-core	
Dependency	RFC 3986	
Test	**/conf/gsml4-lod/codelistURI**	
	Requirement	/req/gsml4-lod/codelistURI
	Test purpose	Ensure that the implementation check that vocabulary terms are dereferenceable URI
	Test method	Visual inspection of the target implementation and check that it provide mechanism to verify that URI are dereferenceable
	Test type	Capability
Test	**/conf/gsml4-lod/identifier**	
	Requirement	/req/gsml4-lod/identifier
	Test purpose	Ensure that the URI identifier can be dereferenced.
	Test method	Visually inspect the target implementation and check that it provides a mechanism to verify that the identifier can be dereferenced and return a representation of the resource assigned to the identifier
	Test type	Capability
Test	**/conf/gsml4-lod/byref**	
	Requirement	/req/gsml4-lod/byref
	Test purpose	Ensure that for properties that reference an external resource using a HTTP URI identifier , this URI is dereferenceable.
	Test method	Visual inspection of the target implementation and check that it provide mechanism to verify that URI are dereferenceable
	Test type	Capability

A.4. Conformance class: GeoSciML Basic Logical Model

Conformance Class	/conf/gsml4-basic	
Requirements	/req/gsml4-basic	
Dependency	/conf/gsml4-core	
Test	/conf/gsml4-basic/geologicfeature-purpose	
	Requirement	/req/gsml4-basic/geologicfeature-purpose
	Test purpose	Ensure that the target implementation enforces the purpose property to be restricted to the values provided in Table 2 (instance, typicalNorm, definingNorm)
	Test method	Visual inspection that the target implementation has a mechanism to limit the property value to those provided in Table 2
	Test type	
Test	/conf/gsml4-basic/geologicevent-non-null	
	Requirement	/req/gsml4-basic/geologicevent-non-null
	Test purpose	Ensure that a GeologicEvent instance has either a olderNamedAge or youngerNamedAge as a non-null value
	Test method	Visual inspection that the target implementation has a mechanism to prevent a GeologicEvent to have both olderNamedAge or youngerNamedAge equals to null.
	Test type	
Test	/conf/gsml4-basic/plane-pol-dip-az-not-null	
	Requirement	/req/gsml4-basic/plane-pol-dip-az-not-null
	Test purpose	Ensure that a GSML_PlanarOrientation instance has either polarity, azimuth or dip as a non-null value
	Test method	Visual inspection that the target implementation has a mechanism to prevent a GSML_PlanarOrientation to have all polarity, azimuth or dip equal to null.
	Test type	Capacity
Test	/conf/gsml4-basic/linear-trend-plunge-not-null	

	Requirement	/req/gsml4-basic/linear-trend-plunge-not-null
	Test purpose	Ensure that a GSML_LinearOrientation instance has either trend or plunge as a non-null value
	Test method	Visual inspection that the target implementation has a mechanism to prevent a GSML_LinearOrientation to have both trend and plunge equals to null.
	Test type	
Test	/conf/gsml4-basic/quantity-range-order	
	Requirement	/req/gsml4-basic/quantity-range-order
	Test purpose	Ensure that a GSML_QuantityRange lowerValue is less or equal to upperValue
	Test method	Visual inspection that the target implementation has a mechanism to constrain lowerValue to be less or equal to upperValue.
	Test type	
Test	/conf/gsml4-basic/quantity-range-repeat	
	Requirement	/req/gsml4-basic/quantity-range-repeat
	Test purpose	Ensure that a GSML_QuantityRange lowerValue and upperValue matches the quantities in the “value” property
	Test method	Visual inspection that the target implementation has a mechanism to constrain lowerValue to match value[0] and upperValue to match value[1]
	Test type	

A.5. Conformance class: GeoSciML Extension Logical Model

Conformance Class	/conf/gsml4-extension	
Requirements	/req/gsml4-extension	
Dependency	/conf/gsml4-basic	
Test	/conf/gsml4-extension/geologicfeature-history	
	Requirement	/req/gsml4-extension/geologicfeature-history
	Test purpose	Ensure that the target implementation restricts GeologicEvent describing the age of GeologicUnit to geologicHistory property
	Test method	Visual inspection that the target implementation has a mechanism to limit GeologicEvent describing age of GeologicFeature to geologicHistory.
	Test type	
Test	/conf/gsml4-extension/contact-chronoboundary	
	Requirement	/req/gsml4-extension/contact-chronoboundary
	Test purpose	Ensure that the target implementation restricts ContactDescription::correlatesWith value to an instance of GeochronologicBondary only when ContactDescription::contactType is ChronostratigraphicBoundary
	Test method	Visual inspection that the target implementation has a mechanism to constrain the value of correlatesWith
	Test type	
Test	/conf/gsml4-extension/slipComponents-slip	
	Requirement	/req/gsml4-extension/slipComponents-slip
	Test purpose	Ensure that a slipComponent has at least one of heave, horizontalSlip or throw as a non-null
	Test method	Visual inspection that the target implementation has a mechanism to constrain on of heave, horizontalSlip or throw to be non-null
	Test type	

A.6. Conformance class: GeoSciML Timescale Logical Model

Conformance Class	/conf/gsml4-timescale	
Requirements	/req/gsml4-timescale	
Dependency	/conf/gsml4-basic	
Test	/conf/gsml4-timescale/start	
	Requirement	/req/gsml4-timescale/start
	Test purpose	Ensure that the start TimeOrdinalEraBoundary is older that the end TimeOrdinalBoundaryEra
	Test method	Visual inspection that the target implementation has a mechanism to check that the age of the start TimeOrdinalEraBoundary is older than the age of the "end" TimeOrdinalEraBoundary
	Test type	

A.7. Conformance class: GeoSciML Borehole Logical Model

Conformance Class	/conf/gsml4-borehole	
Requirements	/req/gsml4-borehole	
Dependency	/conf/gsml4-basic	
Dependency	ISO 19156 Annex A	
Test	/conf/gsml4-borehole/**value-intervalBegin**	
	Requirement	/req/gsml4-borehole/value-intervalBegin
	Test purpose	Ensure that the target implementation enforces the DillingDetails::intervalBegin value is less or equal to DillingDetails::intervalEnd
	Test method	Visual inspection that the target implementation has a mechanism to ensure that DillingDetails::intervalBegin is less or equal to . DillingDetails::intervalEnd
	Test type	
Test	/conf/gsml4-borehole/**drill-interval-1D**	
	Requirement	/req/gsml4-borehole/drill-interval-1D
	Test purpose	Ensure that the target implementation enforces the presence a 1D geometry for DrillingDetails::interval
	Test method	Visual inspection that the target implementation has a mechanism to ensure DrillingDetails::interval is a 1D geometry
	Test type	
Test	/conf/gsml4-borehole/**drill-interval-1D-CRS**	
	Requirement	/req/gsml4-borehole/drill-interval-1D-CRS
	Test purpose	Ensure that the target implementation enforces DillingDetails::intervalEnd geometries CRS to be a valid vertical datum
	Test method	Visual inspection that the target implementation has a mechanism to ensure that DillingDetails::intervalEnd datum is a valid vertical datum.
	Test type	
Test	/conf/gsml4-borehole/**value-mappedIntervalBegin**	

	Requirement	/req/gsml4-borehole/value-mappedIntervalBegin
	Test purpose	Ensure that the target implementation enforces the BoreholeInterval::mappedIntervalBegin value is less or equal to BoreholeInterval::mappedIntervalEnd
	Test method	Visual inspection that the target implementation has a mechanism to ensure that BoreholeInterval::mappedIntervalBegin is less or equal to BoreholeInterval::mappedIntervalEnd
	Test type	
Test	/conf/gsml4-borehole/**interval-1D**	
	Requirement	/req/gsml4-borehole/interval-1D
	Test purpose	Ensure that the target implementation enforces the presence a GM_LineString geometry composed of a pair of 1D coordinates for BoreholeInterval::shape
	Test method	Visual inspection that the target implementation has a mechanism to ensure BoreholeInterval::shape is a GM_LineString composed of a pair of 1D coordinates.
	Test type	
Test	/conf/gsml4-borehole/**interval-1D-CRS**	
	Requirement	/req/gsml4-borehole/interval-1D-CRS
	Test purpose	Ensure that the target implementation constrain the CRS to a relevant vertical datum
	Test method	Visual inspection to check that the target implementation has a mechanism to constrain the CRS to a 1D vertical datum.
	Test type	
Test	/conf/gsml4-borehole/**borehole-position-null**	
	Requirement	/req/gsml4-borehole/borehole-position-null
	Test purpose	Ensure that the target implementation enforce a OGC nil when there are no GM_Point available
	Test method	Visual inspection to check that the target implementation has a mechanism to constrain either a GM_Point or a OGC nil marker.
	Test type	
Test	/conf/gsml4-borehole/**borehole-elevation-dim**	
	Requirement	/req/gsml4-borehole/borehole-elevation-dim

	Test purpose	Ensure that the target implementation enforces that the OriginPosition::elevation has a dimension of 1
	Test method	Visual inspection to check that the target implementation has a mechanism to constrain OriginPosition::elevation coordinate to have a single dimension
	Test type	
Test	/conf/gsml4-borehole/**borehole-elevation-CRS**	
	Requirement	/req/gsml4-borehole/borehole-elevation-CRS
	Test purpose	Ensure that the target implementation enforces the Origin::elevation geometry CRS to be a valid 1D vertical datum
	Test method	Visual inspection to check that the target implementation has a mechanism to constrain OriginPosition::elevation CRS to a value in the range EPSG:5600 to EPSG:5799
	Test type	

A.8. Conformance class: GeoSciML LaboratoryAnalysis-Specimen Logical Model

Conformance Class	/conf/gsml4-lab-analysis	
Requirements	/req/gsml4-lab-analysis	
Dependency	/conf/gsml4-basic	
Dependency	ISO 19156 Annex A	
Test	/conf/gsml4-lab-analysis/sampledFeature	
	Requirement	/req/gsml4-lab-analysis/sampledFeature
	Test purpose	Ensure that the SF_SamplingFeature::sampledFeature is not an instance of SF_SamplingFeature
	Test method	Verify that the target implementation has a mechanism to prevent sampledFeature target to be an instance of SF_SamplingFeature or any of its subtypes.
	Test type	
Test	/conf/ gsml4-lab-analysis/accuracy-measure	
	Requirement	/req/gsml4-lab-analysis/accuracy-measure
	Test purpose	Ensure that DQ_Element::nameOfMeasure and ::result are not null
	Test method	Verify that the target implementation has a mechanism to enforce a non-null value for DQ_Element::nameOfMeasure and DQ_Element::result
	Test type	
Test	/conf/gsml4-lab-analysis/accuracy-vocabulary	
	Requirement	/req/gsml4-lab-analysis/accuracy-vocabulary
	Test purpose	Ensure that nameOfMeasure is a term from a controlled vocabulary
	Test method	Visually check target implementation for the presence of the mechanism that verifies that the nameOfMeasure is a term from a controlled vocabulary
	Test type	

A.9. Conformance class: GeoSciML Lite Logical

Conformance Class	/conf/gsml4-lite	
Requirements	/req/gsml4-lite	
Dependency	/conf/gsml4-core	
Test	/conf/gsml4-lite/geomtype	
	Requirement	/req/gsml4-lite/geomtype
	Test purpose	Ensure that the target implementation only allow a single geometry per instance
	Test method	Visual inspection that the target implementation has a mechanism to limit a single geometry per instance
	Test type	
Test	**/conf/gsml4-lite/string**	
	Requirement	/req/gsml4-lite/string
	Test purpose	Ensure that human readable string are allowed in all properties of type CharacterString
	Test method	Visual inspection that the target implementation does not prevent human readable string (by ensuring that property data types are used)
	Test type	
Test	**/conf/gsml4-lite/datetime**	
	Requirement	/req/gsml4-lite/datetime
	Test purpose	Ensure that all representation of date and time uses ISO8601
	Test method	Visual inspection that the target implementation has mechanism or rules to enforce the usage of ISO8601 date and time
	Test type	
Test	**/conf/gsml4-lite/uri**	
	Requirement	/req/gsml4-lite/uri
	Test purpose	Ensure that all properties ending in URI contain a URI

	Test method	Check that the target implementation enforce the content to RFC 3986
	Test type	
Test	**/conf/gsml4-lite/user-defined**	
	Requirement	/req/gsml4-lite/user-defined
	Test purpose	Ensure that user defined properties conform to GML Simple Feature Level 0
	Test method	Check that the target implementation enforce user defined properties to be conform to GML Simple Feature Level 0
	Test type	
Test	**/conf/gsml4-lite/identifier-unique**	
	Requirement	/req/gsml4-lite/identifier-unique
	Test purpose	Ensure that the identifier is unique for the dataset
	Test method	Check that the target implementation implement a unique key constrain or mechanism to ensure that identifier property is unique.
	Test type	
Test	**/conf/gsml4-lite/identifier-uri**	
	Requirement	/req/gsml4-lite/identifier-uri
	Test purpose	Ensure that the identifier field is formatted as a URI
	Test method	Check that the target implementation implement a formatting constraint on the identifier field that check its compliance to RFC3986
	Test type	
Test	**/conf/gsml4-lite/geologicunitview-representativeLithology**	
	Requirement	/req/gsml4-lite/geologicunitview-representativeLithology
	Test purpose	Ensure that the geologic unit view representative lithology come from a controlled vocabulary
	Test method	Check that the target implementation implements a mechanism to ensure that the term comes from a controlled vocabulary
	Test type	

Test	/conf/gsml4-lite/geologicunitview-representativeAge	
	Requirement	/req/gsml4-lite/geologicunitview-representativeAge
	Test purpose	Ensure that the geologic unit view representative age come from a controlled vocabulary
	Test method	Check that the target implementation implements a mechanism to ensure that the term comes from a controlled vocabulary
	Test type	

Test	/conf/gsml4-lite/geologicunitview-representativeOlderAge	
	Requirement	/req/gsml4-lite/geologicunitview-representativeOlderAge
	Test purpose	Ensure that the geologic unit view representative older age come from a controlled vocabulary
	Test method	Check that the target implementation implements a mechanism to ensure that the term comes from a controlled vocabulary
	Test type	

Test	/conf/gsml4-lite/geologicunitview-representativeYoungerAge	
	Requirement	/req/gsml4-lite/geologicunitview-representativeYoungerAge
	Test purpose	Ensure that the geologic unit view representative older age come from a controlled vocabulary
	Test method	Check that the target implementation implements a mechanism to ensure that the term comes from a controlled vocabulary
	Test type	

Test	/conf/gsml4-lite/boreholeview-elevation-srs	
	Requirement	/req/gsml4-lite/boreholeview-elevation-srs
	Test purpose	Ensure that the elevation is using a valid SRS
	Test method	Check that the target implementation implements a proper CRS reference to a EPSG vertical datum
	Test type	

Test	/conf/gsml4-lite/contactview-contacttype	
	Requirement	/req/gsml4-lite/contactview-contacttype
	Test purpose	Ensure that the contact's contact type come from a controlled vocabulary

	Test method	Check that the target implementation implements mechanism to ensure that the term comes from a controlled vocabulary.
	Test type	
Test	**/conf/gsml4-lite/siteobservationview-symbolRotation**	
	Requirement	/req/gsml4-lite/siteobservationview-symbolRotation
	Test purpose	Ensure that the symbol rotation is the range [0,360[
	Test method	Check that the target implementation implements mechanism to ensure that the rotation is in the range [0,360[
	Test type	

A.10. Conformance class: GeoSciML XML Encoding Abstract Core

Conformance Class	/conf/gsml4xsd	
Requirements	/req/gsml4xsd	
Dependency	OGC 10-025r1 OMXML Observations and Measurements - XML Implementation	
Test	/conf/gsml4xsd/xsd	
	Requirement	/req/gsml4xsd/xsd
	Test purpose	Ensure that GeoSciML XML documents are valid
	Test method	Perform a XSD validation on a XML instance document. Test succeeds if the validation does not report any error.
	Test type	
Test	/conf/gsml4xsd/sch	
	Requirement	/req/gsml4xsd/sch
	Test purpose	Ensure that encoding rules defined in the specification are met
	Test method	Perform a schematron validation on the XML instance. Test succeeds if the validation does not report any failed rules.
	Test type	
Test	/conf/gsml4xsd/codelist	
	Requirement	/req/gsml4xsd/codelist
	Test purpose	Ensure that vocabulary xlink:href contain an absolute http URI and this URL resolves to relevant content
	Test method	Test the URI on the web. If the URI does not resolve or return a 4xx error, the test fails.
	Test type	
Test	/conf/gsml4xsd/time-zone	
	Requirement	/req/gsml4xsd/time-zone
	Test purpose	Ensure that time zone are expressed explicitly
	Test method	Visually inspect instance to validate the presence of time zone indicators.

	Test type	

A.11. Conformance class: GeoSciML Basic XML Encoding

Conformance Class	/conf/gsml4xsd-basic	
Requirements	/req/gsml4xsd-basic	
Dependency	/conf/gsml4xsd/core	
Test	/conf/gsml4xsd-basic/xsd	
	Requirement	/req/gsml4xsd-basic/xsd
	Test purpose	Ensure that GeoSciML Basic XML documents are valid
	Test method	Perform a XSD validation on a XML instance document. Test succeeds if the validation does not report any error.
	Test type	
Test	/conf/gsml4xsd-basic/sch	
	Requirement	/req/gsml4xsd-basic/sch
	Test purpose	Ensure that encoding rules defined in the specification are met
	Test method	Perform a schematron validation on the XML instance. Test succeeds if the validation does not report any failed rules.
	Test type	

A.12. Conformance class: GeoSciML Extension XML Encoding

Conformance Class	/conf/gsml4xsd-extension	
Requirements	/req/gsml4xsd-extension	
Dependency	/conf/gsml4xsd/basic	
Test	/conf/gsml4xsd-extension/xsd	
	Requirement	/req/gsml4xsd-extension/xsd
	Test purpose	Ensure that GeoSciML Extension XML documents are valid
	Test method	Perform a XSD validation on a XML instance document. Test succeeds if the validation does not report any error.
	Test type	
Test	/conf/gsml4xsd-extension/sch	
	Requirement	/req/gsml4xsd-extension/sch
	Test purpose	Ensure that encoding rules defined in the specification are met
	Test method	Perform a schematron validation on the XML instance. Test succeeds if the validation does not report any failed rules.
	Test type	

A.13. Conformance class: GeoSciML GeologicTime XML Encoding

Conformance Class	/conf/gsml4xsd-geologictime	
Requirements	/req/gsml4xsd-geologictime	
Dependency	/conf/gsml4xsd/core	
Test	/conf/gsml4xsd-geologictime/xsd	
	Requirement	/req/gsml4xsd-geologictime/xsd
	Test purpose	Ensure that GeoSciML Geologic Time XML documents are valid
	Test method	Perform a XSD validation on a XML instance document. Test succeeds if the validation does not report any error.
	Test type	
Test	/conf/gsml4xsd-geologictime/sch	
	Requirement	/req/gsml4xsd-geologictime/sch
	Test purpose	Ensure that encoding rules defined in the specification are met
	Test method	Perform a schematron validation on the XML instance. Test succeeds if the validation does not report any failed rules.
	Test type	

A.14. Conformance class: GeoSciML Borehole XML Encoding

Conformance Class	/conf/gsml4xsd-borehole	
Requirements	/req/gsml4xsd-borehole	
Dependency	/conf/gsml4xsd/core	
Dependency	OGC 10-025r1 OMXML	
Test	/conf/gsml4xsd-borehole/xsd	
	Requirement	/req/gsml4xsd-borehole/xsd
	Test purpose	Ensure that GeoSciML Borehole XML documents are valid
	Test method	Perform a XSD validation on a XML instance document. Test succeeds if the validation does not report any error.
	Test type	
Test	/conf/gsml4xsd-borehole/sch	
	Requirement	/req/gsml4xsd-borehole/sch
	Test purpose	Ensure that encoding rules defined in the specification are met
	Test method	Perform a schematron validation on the XML instance. Test succeeds if the validation does not report any failed rules.
	Test type	

A.15. Conformance class: GeoSciML LaboratoryAnalysis-Specimen XML Encoding

Conformance Class	/conf/gsml4xsd-lab	
Requirements	/req/gsml4xsd-lab	
Dependency	/conf/gsml4xsd/core	
Dependency	OGC 10-025r1 OMXML	
Test	/conf/gsml4xsd-lab/xsd	
	Requirement	/req/gsml4xsd-lab/xsd
	Test purpose	Ensure that GeoSciML Laboratory and Analysis XML documents are valid
	Test method	Perform a XSD validation on a XML instance document. Test succeeds if the validation does not report any error.
	Test type	
Test	/conf/gsml4xsd-lab/sch	
	Requirement	/req/gsml4xsd-lab/sch
	Test purpose	Ensure that encoding rules defined in the specification are met
	Test method	Perform a schematron validation on the XML instance. Test succeeds if the validation does not report any failed rules.
	Test type	

A.16. Conformance class: GeoSciML Lite XML Abstract Encoding

Conformance Class	/conf/gsml4xsd-lite	
Requirements	/req/gsml4xsd-lite	
Dependency	OGC 05-033r9 : Annex A	
Test	/conf/gsml4xsd-lite/SF-0	
	Requirement	/req/gsml4xsd-lite/SF-0
	Test purpose	Ensure that XML instance is compliant to OGC Simple Feature SF-0
	Test method	Perform the test in OGC 05-033r9 Annex A
	Test type	

A.17. Conformance class: GeoSciML Lite XML Encoding for GML

Conformance Class	/conf/gsml4xsd-lite-31	
Requirements	/req/gsml4xsd-lite-31	
Dependency	/req/gsml4xsd-lite	
Test	/conf/gsml4xsd-lite-31/xsd	
	Requirement	/req/gsml4xsd-lite-31/xsd
	Test purpose	Ensure that GeoSciML Portrayal XML documents are valid
	Test method	Perform a XSD validation on a XML instance document. Test succeeds if the validation does not report any error.
	Test type	
Test	/conf/gsml4xsd-lite-31/sch	
	Requirement	/req/gsml4xsd-lite-31/sch
	Test purpose	Ensure that encoding rules defined in the specification are met
	Test method	Perform a schematron validation on the XML instance. Test succeeds if the validation does not report any failed rules.
	Test type	

Annex B. Revision history

Date	Release	Author	Paragraph modified	Description
2015-10-02	1	Eric Boisvert	All	Moved text into standard OGC template
2015-10-	1	Eric Boisvert	Portrayal and basic	Group review of some clauses at Ispra meeting.
2016-01-05	1	Eric Boisvert	All	Global review of text for first draft
2016-02-03	1	Ollie Raymond	Many	General review
2016-04-02	1	Eric Boisvert	All	Review, document structure, Bibliography
2016-05-04	1	Marcus Sen	All	Editorial changes, removed all tracks
2016-05-26	2	Eric Boisvert	Lite (previously Portrayal)	Portrayal -> Lite (Req and Conformance)
2016-06-02	2	Eric Boisvert	Lite (previously Portrayal) Conceptual	Added mapping table for Lite->GeoSciML Added a small text for conceptual model + requirement class + conformance class
2016-06-25	2	Eric Boisvert, Oliver Raymond, Carlo Cipolloni	All	Updated Etna example Addressed OGC OAB issues
2016-07-02	2	Eric Boisvert	All	Added discussion on Conceptual model. Move Lite (old Portrayal) after other package to enforce the fact that Lite is a transformation of the other packages.
2016-08-02	2	Eric Boisvert, Oliver Raymond	All	Addressed remaining comments Updated all diagram to 4.1
2016-08-03	2	Eric Boisvert	All	Revised conformance classes
2016-08-05	2	Eric Boisvert	All	Check if descriptions of req in summary matched descriptions in text
2016-08-12	2	Ollie Raymond	All	Final checks for grammar, typos, formatting.

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