



GeoSciML Cookbook

How To Map Data to GeoSciML Version 2



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1 INTRODUCTION

1.1 The purpose of this cookbook

The GeoSciML application is a standards-based data format that provides a framework for application-neutral encoding of geoscience thematic data and related spatial data. At present the scope is delimited by the information generally shown on geological maps, along with boreholes and field observations. This document is written to assist organisations wishing to make use of the GeoSciML data exchange standard. This will include **Level 2** participants in OneGeology who will be serving GeoSciML in a WFS.

This cookbook describes the GeoSciML logical model and provides information on its scope and the background to its development in sections 2 and 3. As the GeoSciML logical data model is complex, and designed to handle a wide range of different types of geoscience data, there are many instances where it is possible to encode information, using the model, in more than one way. This means that use of the GeoSciML data exchange format, of itself, is insufficient to lead to the interoperability which was the main objective behind the development of GeoSciML. For this reason guidelines on how to map particular types of data to GeoSciML have been developed, and these are described in section 4 through the use of exemplar GeoSciML instance documents.

1.2 Who should be using this cookbook?

The cookbook is designed to assist users map their data to the GeoSciML logical data model. In most cases users with digital geoscience data will have their own formalised model of some type, although this will not always be the case. Where a formalised user data model exists then the process of mapping data to GeoSciML will largely involve mapping features/entities in the user model to their equivalents in the GeoSciML logical data model. Where no such user model exists then mapping must be carried out direct from the data.

To carry out the mapping, from either a model or direct from data, requires staff with geoscientific knowledge, familiarity with the user's own data and data model, and an understanding of the UML formalisation used in documenting GeoSciML. These staff are likely to be geoscientists, possibly those who were involved in developing the organisation's own data model, and it is these people who are seen as the main users of this cookbook.

1.3 Related documentation

Materials and documentation on GeoSciML have been produced by the CGI Interoperability Working Group (IWG) and are available "as is" for download from http://www.cgi-iugs.org/tech_collaboration/data_model/downloads.html. It is the aim of the Working Group to ensure that the most current materials and information relating to GeoSciML are available from this site. The supporting materials most relevant to this cookbook include:

- Full documentation of the GeoSciML model. This is generated automatically from the GeoSciML UML diagrams and draws on the scope notes in those diagrams. It describes the model in more detail than is done in section 3 of this cookbook and should be seen as the definitive reference. This full documentation, however, does not include any best practice guidance
- An Enterprise Architect version of the UML for the CGI packages
- This cookbook

In addition the page gives links to a:

- GeoSciML Resources Repository (<http://www.geosciml.org/>) which has tagged versions of the model, schema, examples and documentation, for all versions of GeoSciML
- Twiki site (<https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/GeoSciMLModel>) with full background information on the use and development of the GeoSciML model and schema

Although use of GeoSciML is open to the geoscience community, in order to ensure the integrity of the GeoSciML standard across the community the IWG requests that the following points be applied to any work involving GeoSciML:

1. full compliance with existing GeoSciML conformance criteria
2. the IWG and its GeoSciML products are not misrepresented or misused
3. the IWG retains full copyright to all IWG and GeoSciML names and products, including logos, text, images and technical materials
4. the GeoSciML name and associated namespaces, as well as the IWG name and associated task group names, are reserved strictly for IWG activities and products
5. the GeoSciML products developed by the IWG may be freely copied and used within third-party information systems, with acknowledgements as per (8) below
6. the GeoSciML products developed by the IWG are not to be modified by third-parties, except as part of the revision process within the IWG
7. extensions to GeoSciML by third-parties remain distinct from GeoSciML, exist in non-GeoSciML namespaces, and are not to be represented as IWG or GeoSciML products
8. acknowledgement of GeoSciML and the IWG is made in all communications and products related to work involving GeoSciML or the IWG, with appropriate citation
9. the IWG gives no warranty, expressed or implied, as to the quality or accuracy of the information supplied, or to the information's suitability for any use. The IWG accepts no liability whatever in respect of loss, damage, injury or other occurrence however caused

2 BACKGROUND AND SCOPE

2.1 Background to the model development

It is becoming increasingly important to be able to query and exchange digital geoscientific information between data providers and users. Technological opportunities arising from the development of geospatial information standards are making such interoperability a viable proposition. In order to investigate these opportunities a meeting of international geoscience data providers, mainly geological surveys, was held in Edinburgh in 2003. Following from this meeting the Interoperability Working Group (IWG) under the auspices of the IUGS Commission for the Management and Application of Geoscience Information (CGI) was set up.

The IWG was tasked with developing a conceptual geoscience data model, mapping this to a common interchange format, and demonstrating the use of this interchange format through the development of a testbed. Active participants in the working group are drawn from BGS (United Kingdom), BRGM (France), CSIRO (Australia), GA (Australia), GSC (Canada), GSV (Australia), APAT (Italy), JGS (Japan), SGU (Sweden) and USGS (USA). The ultimate objective of the working group is to enable seamless web integration of select information hosted at different agencies in varied formats.

More specific objectives are to:

- develop a conceptual model of geoscientific information drawing on existing data models
- implement an agreed subset of this model in an agreed schema language
- implement an XML/GML encoding of the model subset
- develop a testbed to illustrate the potential of the data model for interchange
- identify areas that require standardised classifications in order to enable interchange

GeoSciML development work is mainly carried out on a Twiki site (<https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/WebHome>) where detailed information about all aspects of the work can be found. We welcome participation in these discussions from all those interested in the development of geoscience interchange standards. A password is required for such participation and you can apply for one by mailing John Laxton (jll@bgs.ac.uk) giving your accreditation and outlining your interest and involvement in geoscience interoperability.

Occasional face to face meetings are also held. These are by invitation to those who have been active in the relevant Twiki discussions and are designed to provide a concentrated period of development and decision making.

2.2 Purpose of the model

In order for there to be interchange of information there has to be agreement on the nature and structure of the information to be interchanged. The simplest way of achieving this would be if all geoscience data providers shared a common database structure. However, because data providers already have their own database implementations, and the information gathered and held by different providers is not exactly the same, this option is not possible. The solution is to agree a common conceptual data model, to which data held in existing databases can be mapped. Such a data model needs to identify the objects being described (eg 'faults'), their properties (eg 'displacement') and the relations between objects (eg 'faults are a type of Geologic Structure'). Such a model can be described graphically using Universal Modeling Language (UML), an ISO standard.

Having agreed a conceptual data model it needs to be mapped on to an interchange format. The GeoSciML application is a standards-based data format that provides a framework for application-neutral encoding of geoscience thematic data and related spatial data. GeoSciML is based on Geography Markup Language (GML – ISO DIS 19136) for representation of features and geometry, and the Open Geospatial Consortium (OGC) Observations and Measurements standard for observational data. Geoscience-specific aspects of the schema are based on a conceptual model for geoscience concepts which includes packages for GeologicUnit, GeologicStructure, EarthMaterial, and Borehole information. Development of controlled vocabulary resources for specifying content to realize semantic data interoperability is underway.

Intended uses are for data portals publishing data for customers in GeoSciML, for interchanging data between organizations that use different database implementations and software/systems environments, and in particular for use in geoscience web services. Thus, GeoSciML allows applications to utilize globally distributed geoscience data and information.

GeoSciML is *not* a database structure. GeoSciML defines a format for data interchange. Agencies can provide a GeoSciML *interface* onto their existing data base systems, with no restructuring of internal databases required (Figure 1).

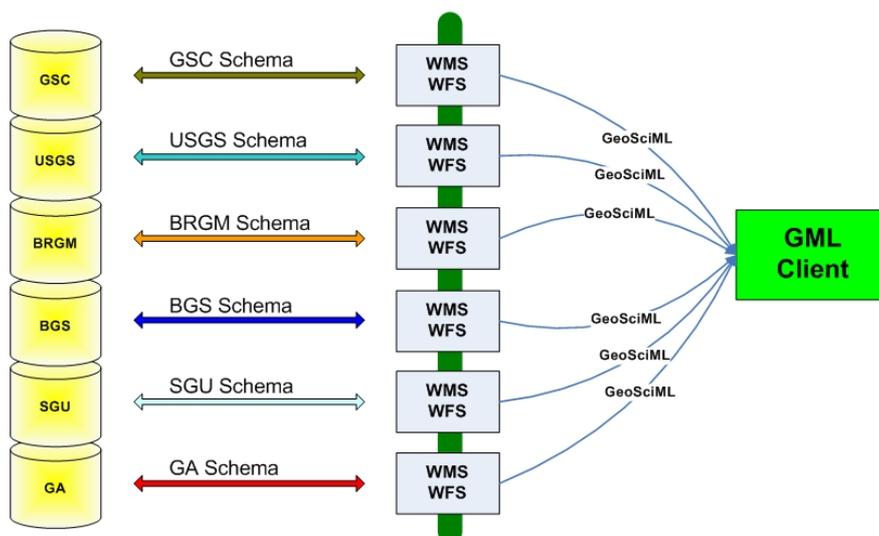


Figure 1: Architecture of a GeoSciML web service

2.3 Scope of the model

Developing a conceptual data model for geoscience is a major piece of work and in the current phase of development the scope has been restricted to those geoscience objects which form the main components of a geological map, as well as boreholes and field observations.

The GeoSciML model will never provide definitions of everything in geoscience because other groups may have governance of particular areas of geoscience. The IWG aims to coordinate with the work of these other groups.

GroundwaterML is an example of a derived implementation of GeoSciML. It is also the first official collaboration between GeoSciML and an external exchange model group.

MineralOccurrences is an example of an inherited implementation of GeoSciML. It is being developed by the Australian Government Geologists Information Committee (GGIC) as a model to deliver mineral occurrences information as a WMS/WFS. Australian State, territory and federal organizations presently govern the model.

GeoSciML has not got a clearly defined ultimate limit to its scope. It has been developed primarily by Geological Survey Organisations (GSOs) to assist them in the interchange and delivery of their data, although it has always been envisaged that it would be adopted by other geoscience data providers. GeoSciML has been developed in the first instance to handle the interpretative information shown on geological maps, as this is GSOs most widely used data set, but it also handles some of the data underlying the map. The extent to which the need to exchange other types of geoscience data will be met by extending GeoSciML, as opposed to using standards developed elsewhere, will depend on what external standards are developed. GeoSciML will always aim to adopt external standards where possible and GeoSciML will only be extended where no such standards exist or are being developed by other governance bodies.

3 OVERVIEW OF THE MODEL

3.1 Methodology and documentation

3.1.1 UML model

GeoSciML is formally defined by a UML model, also known as an "Application Schema" (following the terminology of ISO 19109). In addition, the domain for certain feature-properties will be provided, typically serialized as GML Dictionaries. Designators for key components that are required for deployment in a distributed environment follow the CGIIdentifierScheme (<https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/CGIIdentifierScheme>).

The reference version of the Application Schema is provided as XMI documents. (XMI is an XML serialization of UML).

The UML profile used follows the ISO 19103 profile, and in particular using the rules from ISO 19136:2007 (GML 3.2.1) Annex E as summarized in [https://www.seegrid.csiro.au/twiki/bin/view/AppSchemas/UmlGml#ISO TC 211 Profile of UML](https://www.seegrid.csiro.au/twiki/bin/view/AppSchemas/UmlGml#ISO_TC_211_Profile_of_UML)

Implementation views of GeoSciML are provided as a GML-conformant XML Schema and as a set of HTML documents organized in a frame-set. The implementation views are generated using an automated process, starting with the XMI.

3.1.2 XML Schema

The schema is automatically generated from the UML model following the rules described in [ISO 19136:2007](https://www.iso.org/standard/50022.html) (GML 3.2.1) Annex E with the following variations:

GeoSciML v2 is currently bound to GML v3.1.1.

The rule for encoding <<Union>> classes follows [https://www.seegrid.csiro.au/twiki/bin/view/AppSchemas/Uml2GMLAS#4 Class association pattern target](https://www.seegrid.csiro.au/twiki/bin/view/AppSchemas/Uml2GMLAS#4_Class_association_pattern_target).

Additional stereotypes are used as described in [https://www.seegrid.csiro.au/twiki/bin/view/AppSchemas/UmlGml#ISO TC 211 Profile of UML](https://www.seegrid.csiro.au/twiki/bin/view/AppSchemas/UmlGml#ISO_TC_211_Profile_of_UML).

3.1.3 Documentation

Full documentation of the model may be viewed from http://www.cgi-iugs.org/tech_collaboration/data_model/downloads.html

3.1.4 Working with the UML model

GeoSciMLv2 is available as a set of XMI documents at <http://www.geosciml.org/geosciml/2.0/xmi/>.

The GeoSciML design team uses the Enterprise Architect (EA) UML tool to maintain the model. A free EA viewer (EAViewer.exe, intended for distribution with such models) can be obtained from http://www.sparxsystems.com/products/ea_downloads.html.

When loaded in EA, the model is found under [Model]->[GeoScience Resources]->[CGIWorld]->[GeoSciML].

3.1.5 Working with the XML Schema

The XML Schema representation of GeoSciML can be used to validate GeoSciML instance documents. The GeoSciMLv2 specific schemas are available at <http://www.geosciml.org/geosciml/2.0/xsd/>. These import schemas from other namespaces which can be found at a number of locations.

During development successful validation can be dependent on using particular versions of these other schemas. You may need to configure your validation environment specially to do this - see <https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/ConfiguringXmlValidatorsForGeoSciML> for notes on this.

3.2 Model Packages

There are twelve distinct packages in the GeoSciML data model, and in this section the UML of each will be shown and the key points of each identified. The relationships between the packages will also be identified.

3.2.1 Geologic Feature

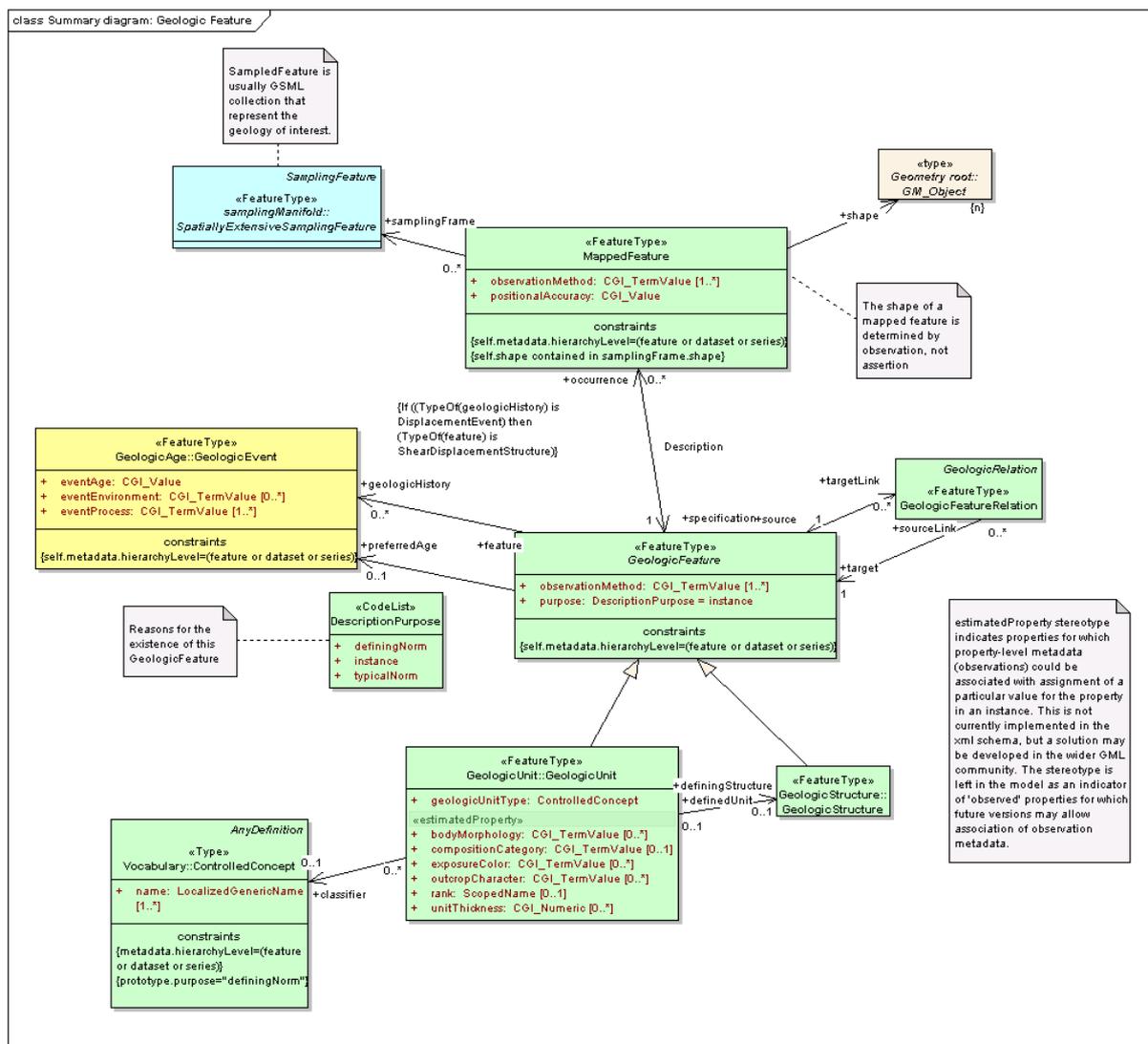


Figure 2: Summary UML diagram for the Geologic Feature package

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

A mandatory property of GeologicFeature is 'purpose' which states whether the GeologicFeature is an instance or normative description. On published geologic maps, for example, it is generally the case that normative GeologicUnits are shown, for which a standard description is given in a

StratigraphicLexicon. Survey scale, or field, maps on the other hand may describe unclassified instances of GeologicUnits.

The observationalMethod properties of both MappedFeature and GeologicFeature enable the distinct methodologies for observing each of these to be recorded. For example a MappedFeature might be observed through field observation (mapping) while the normative GeologicFeature it is an occurrence of may have been observed (defined) through summarising published descriptions.

Each MappedFeature is associated with a SamplingFrame that indicates the spatial reference frame within which the MappedFeatures have been observed, such as a surface of mapping or a borehole.

A GeologicFeature can be either a GeologicUnit or GeologicStructure (described in sections 3.2.2 and 3.2.4 respectively).

The age of GeologicFeatures is described in terms of GeologicEvents (see section 3.2.6). This can either be as a single GeologicEvent giving a preferredAge for the GeologicFeature, or as a series of one or more GeologicEvents describing the geologicHistory of the GeologicFeature.

The relationship between GeologicFeatures can be described using GeologicFeatureRelation (see section 3.2.8). Relationships are described from a source to a target - for example a source GeologicFeature might be an intrusive igneous rock body which could point to a target indicating the host rock body. In this case the 'relationship' attribute would be 'intrudes'. Other appropriate relationship attributes might include: overlies, offsets, crosscuts, folds, etc.

3.2.2 Geologic Unit

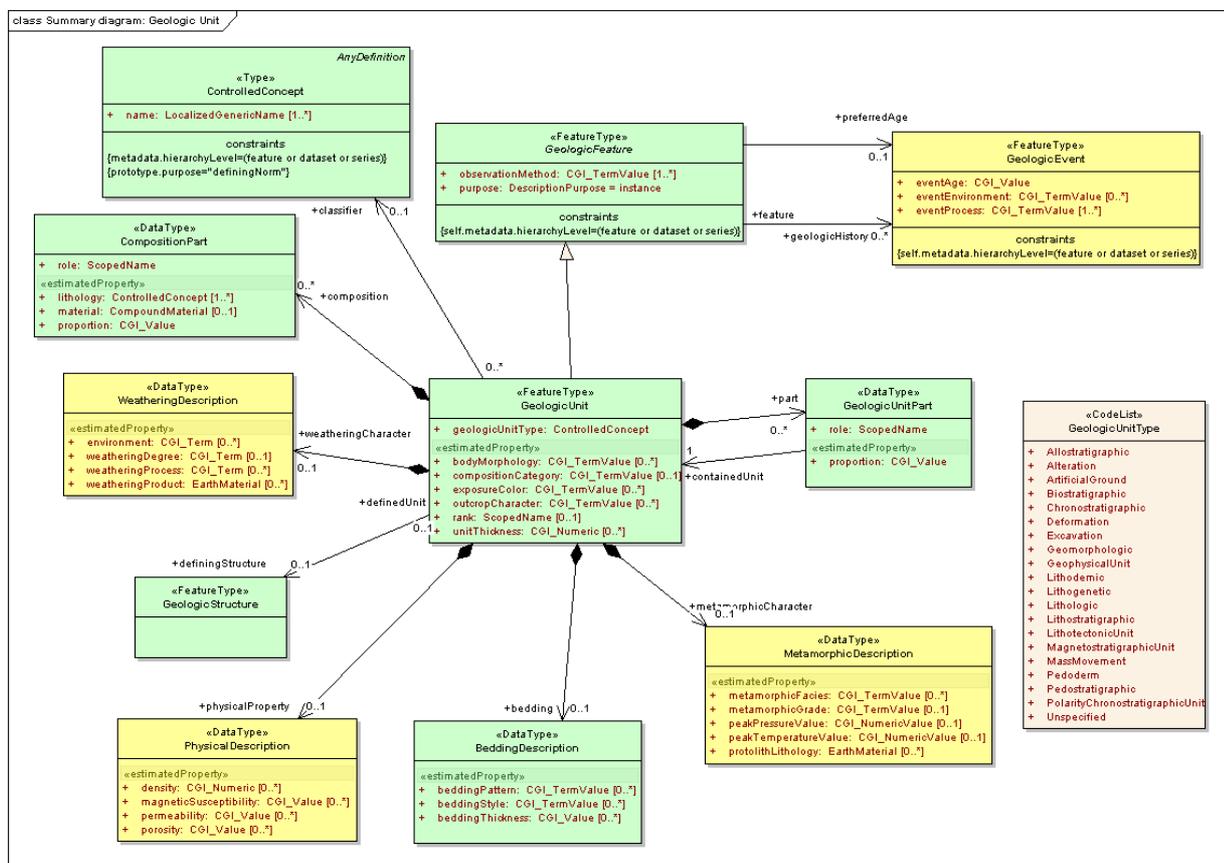


Figure 3: Summary UML diagram for the Geologic Unit package

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

Geologic units have no specialisations, the type of GeologicUnit being defined by the geologicUnitType property. This means that there is no control, through the model, of the required properties for any particular geologicUnit type. For example a lithologic unit logically must have a composition value, but this constraint can only be enforced by applications using GeoSciML.

A GeologicUnit can be classified with a ControlledConcept (see section 3.2.10). The ControlledConcept can be a normative description of a GeologicUnit, defined in a StratigraphicLexicon for example

GeologicUnitPart allows for composite geologic units, made up of other geologic units, to be described. This can be used for formal stratigraphic hierarchies as well as informal relationships.

The composition of a GeologicUnit is described using CompositionPart. A GeologicUnit can have a single CompositionPart describing the entire unit, in which case the 'proportion' property would be 'only_part' or 100%, or it can be made up of several CompositionParts with the relationship of each to the whole GeologicUnit described by the 'role' property (e.g. vein, interbedded constituent, layers, dominant constituent). The lithology is described using a lithology term (eg 'conglomerate') drawn from an EarthMaterial vocabulary, but can in addition have a specific EarthMaterial description using the 'material' property to provide more detailed information about the lithology of the particular GeologicUnit.

The MetamorphicDescription, PhysicalDescription, WeatheringDescription and BeddingDescription data types allow the recording of certain specific properties of GeologicUnits. It is appreciated that the properties included, particularly in the case of PhysicalDescription, are a subset of those which may be required. Additional properties may be added in future versions of the model in light of user requirements.

3.2.3 Earth Material

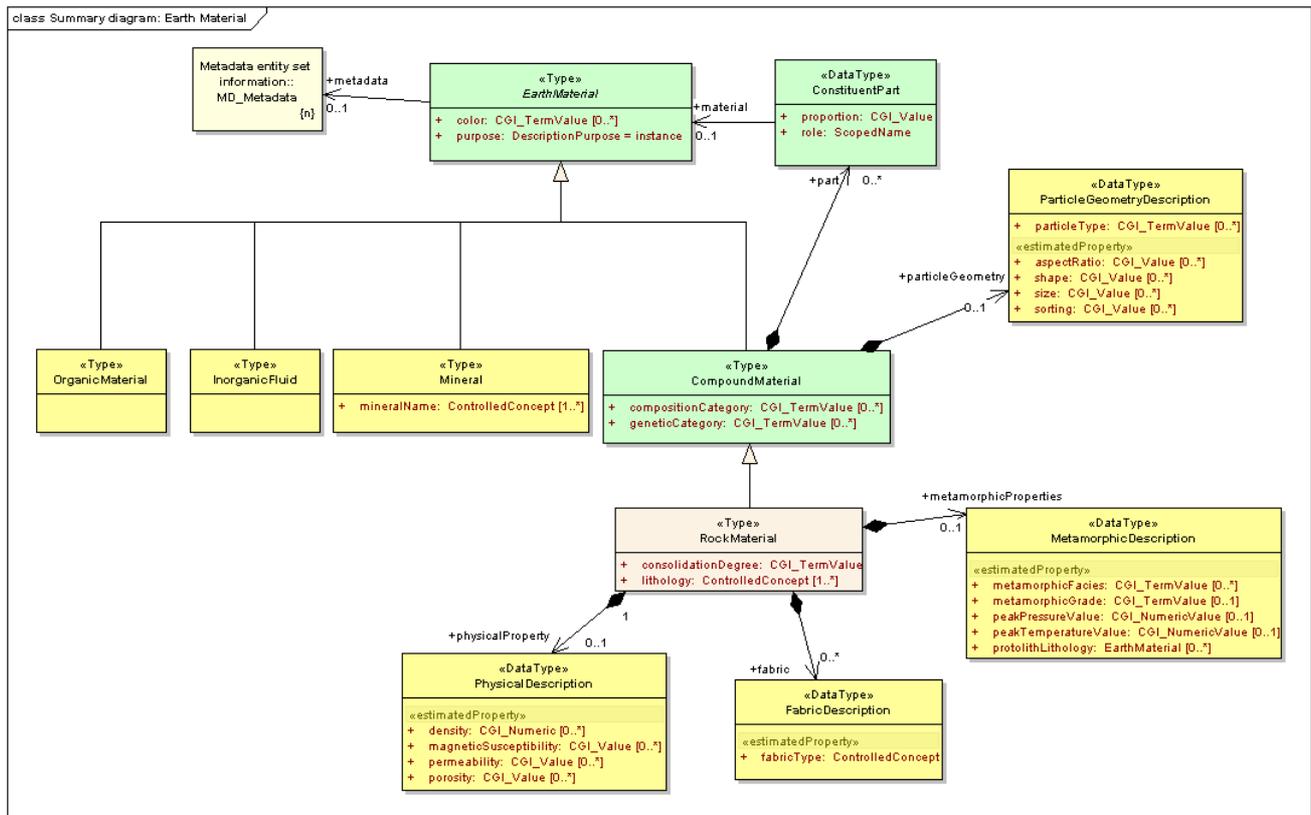


Figure 4: Summary UML diagram for the Earth Material package

The EarthMaterial package allows for the description of naturally occurring substances in the earth. These substances can be either discrete components, such as a specific type of mineral, or CompoundMaterials built up from either discrete components or other CompoundMaterials. At present RockMaterial is the only type of CompoundMaterial modelled, and this includes both consolidated and unconsolidated materials.

A CompoundMaterial can be described in terms of its ConstituentParts, each of which has a role and a proportion property to allow, for example, for the description and relative abundance of the framework and matrix in a rock such as oolitic limestone. The description of a CompoundMaterial can be enhanced using the ParticleGeometryDescription which provides additional properties relating to particle geometry such as size and shape.

The MetamorphicDescription, PhysicalDescription and FabricDescription data types allow the recording of certain specific properties of RockMaterials. It is appreciated that the properties included, particularly in the case of the PhysicalDescription, are a subset of those which may be required. Additional properties may be added in future versions of the model in light of user requirements. FabricDescription is distinguished from ParticleGeometryDescription on the criterion that ParticleGeometryDescription is preserved if a CompoundMaterial is disaggregated, while FabricDescription is not defined if the material is disaggregated.

The Geologic Structure package models most types of geologic structure. Primary sedimentary and igneous structures, as well as tectonic structures, are included. Many of the structural properties concern orientation measurements and specific orientation data types are used for recording these (see section 3.2.9).

ShearDisplacementStructures include both Faults and FaultSystems, with the latter described in terms of their component Faults. The DisplacementValue can be described both as a single totalDisplacement for the structure, and as a series of incrementalDisplacements each associated with a particular DisplacementEvent. The DisplacementValue is recorded in terms of its SeparationValue and NetSlipValue and, optionally, as SlipComponent vectors. Physical properties, such as porosity and permeability, can be recorded for ShearDisplacementStructures.

Both Folds and FoldSystems are modelled, the latter described in terms of their component Folds. Foliation is modelled and includes Layering.

Contacts are included as a type of Structure and the BoundaryRelationship between the GeologicUnits either side of the Contact can be described along with their descriptive properties.

3.2.5 Fossil

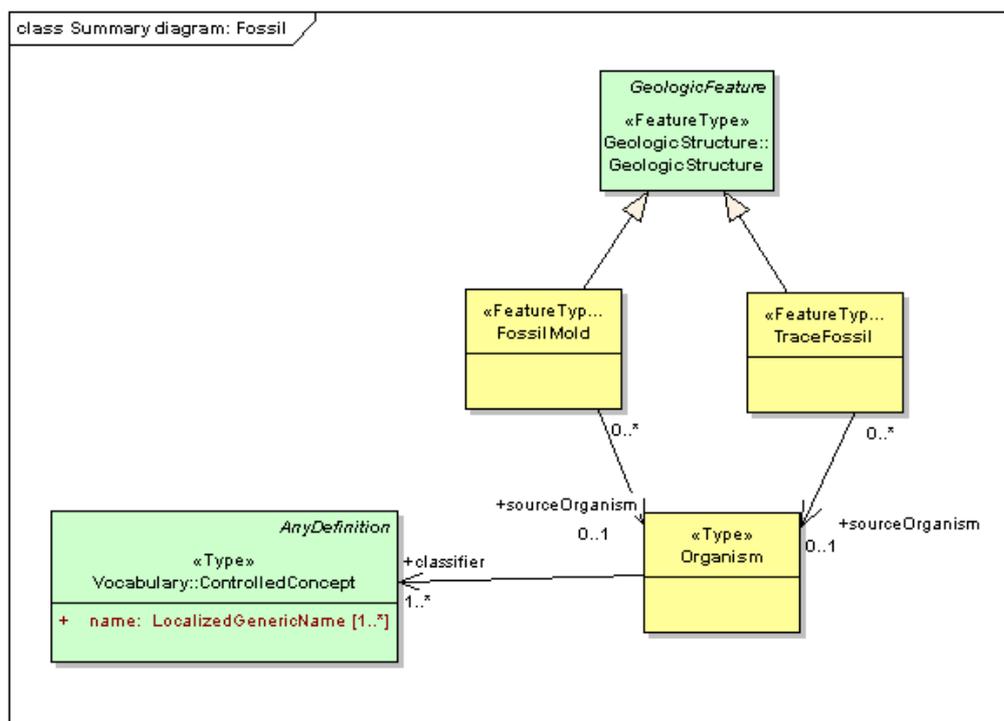


Figure 6: Summary UML diagram for the Fossil package

The GeoSciML Fossil package is not attempting to model taxonomy. ‘Organism’ is a broad class to represent any living or once living thing and can be classified using a vocabulary of ControlledConcepts (see section 3.2.10). This vocabulary could be a full taxonomy for fossils. Fossils have a limited role in the GeoSciML model and are modelled only in their role as types of GeologicStructure, either TraceFossils or FossilMolds.

3.2.6 Geologic Age

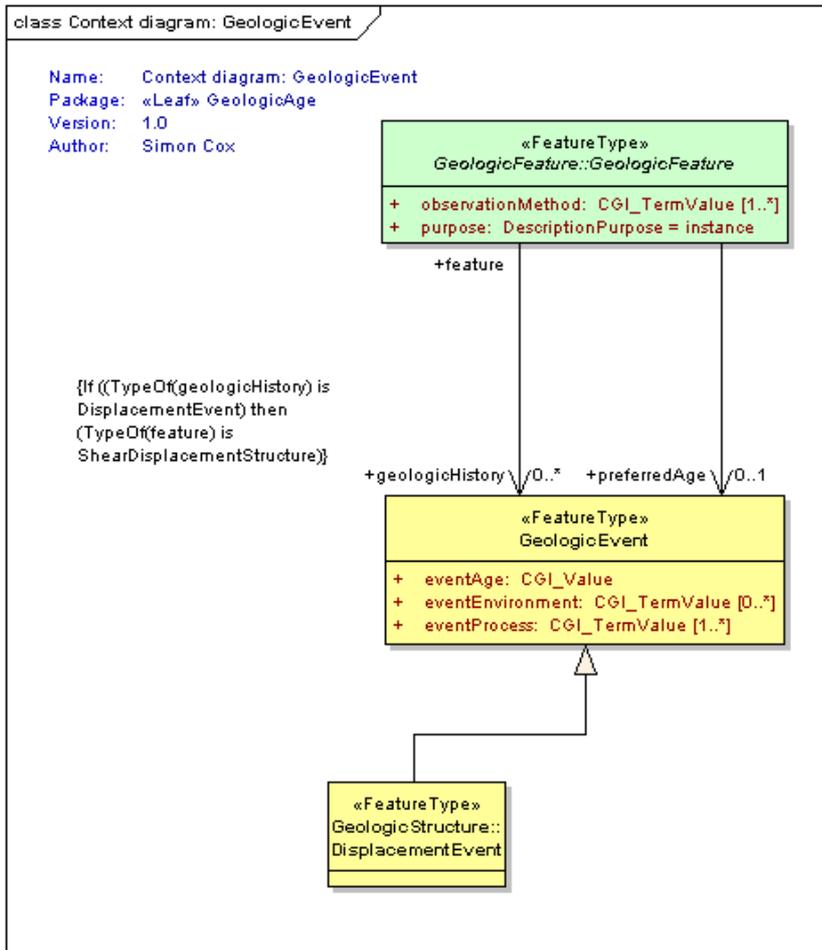


Figure 7: Summary UML diagram for the Geologic Age package

GeologicAge is defined in terms of GeologicEvents which, in addition to age, may have information about the eventEnvironment (the physical setting within which a GeologicEvent takes place) and the eventProcess (a function that acts on one geologic entity to produce another geologic entity at a later time) recorded.

GeologicEvents record the age and history of GeologicFeatures (see section 3.2.1). DisplacementEvents are the particular type of GeologicEvents associated with ShearDisplacementStructures (see section 3.2.4).

3.2.7 Boreholes and Observations

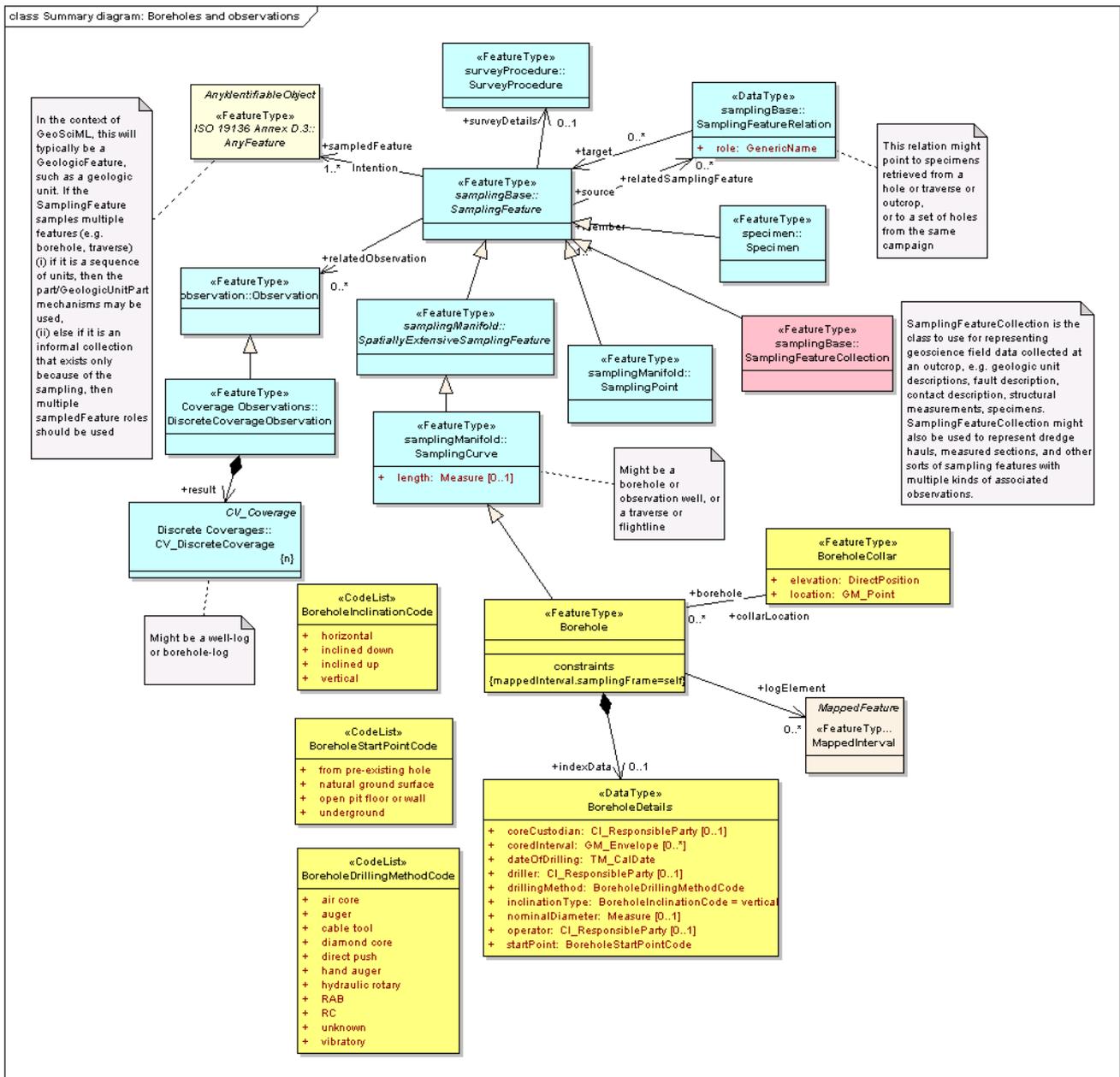


Figure 8: Summary UML diagram for the Boreholes & Observations package

Boreholes are modelled as a special type of SamplingCurve feature but borehole logs can be described in two ways in the GeoSciML model – either as a series of Observations or as a series of logElements which associate to MappedIntervals. MappedIntervals are a type of MappedFeature (see Section 3.2.1) and in this approach a borehole can be considered as being akin to a linear geological map. The GeoSciML Boreholes and Observations package re-uses standard components from the OGC Observations and Measurements package.

A borehole is a feature whose median axis is a curve. Related observations and measurements are made on points or intervals at depths measured from the collar along the borehole curve. Observations may concern, for example, lithology, stratigraphy (category results), porosity,

geophysical logs data, and ore-grades (numerical results). In the case of holes with non-constant diameter, the variation of the diameter may also be described as a log.

The shape of the boreholes (median axis of the borehole) is a 3D curve, which in the simplest cases may be vertical and straight, but is commonly deviated, and often not straight. The axis-shape may be described by means of another log known as the “survey” (3-D direction as a function of depth) which may be converted (“de-surveyed”) to obtain the shape in an x-y-z reference frame.

A borehole is associated with one or more domain features which it samples: for instance, the GeologicalUnit intersected by the borehole. A borehole may also be associated with related sampling features. This allows a set of boreholes to be grouped as a campaign, or specimens to be associated with boreholes, boreholes with mines, etc.

While boreholes may carry various kinds of observation, in a geological mapping context, lithology logs are a key information type. There are two ways to describe these:

1. The lithology log is reported as the result of a related observation in which the association points from the borehole sampling frame to the observations made within that sampling frame. This point of view is natural when comparing multiple logs of different properties.
2. The lithology log is a collection of MappedIntervals (i.e. occurrences of GeologicUnits) whose sampling frame is a sampling curve describing the borehole – i.e. **classification-centric**. In this view the association points from the borehole sampling frame to the MappedIntervals. This point of view is natural when comparing a borehole log with other representations of the same property, perhaps sampled in a different frame (e.g. map or section).

When to use which approach?

1. The first approach (borehole observations) is important during observation/data-collection and for re-examination through the lens of an observational campaign.
2. The second approach (mapped features) is important after interpretation, and is used later on during compilation.

With the second approach, it is highly convoluted to also include measurements of continuously varying properties, such as ore-grades, porosity, etc. Hence, the first approach is recommended when it is required to compare geologic features (e.g. units) and ore-grade within a hole. However, the second approach is more convenient to compare a geological interpretation from a borehole with a 2-D or 3-D model described as a set of mapped features (i.e. a geologic map).

Many measurements, such as magnetic susceptibility, could be recorded either as a property of the GeologicUnit specifying the MappedInterval or as an Observation. If the borehole has been divided into MappedIntervals, and the measurement has been made for that MappedInterval specifically to describe a property of the GeologicUnit specifying the MappedInterval, then it should be recorded as a property of the GeologicUnit. If on the other hand the measurement has been made for a borehole interval defined solely for sampling purposes (eg at regular intervals down the borehole) then it should be recorded as an Observation.

Geological observations are not only made in boreholes and SamplingFeatureCollection is the class to use for representing geoscience field data collected at an outcrop, e.g. geologic unit descriptions, fault description, contact description, structural measurements, specimens.

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

3.2.8 Geologic Relation

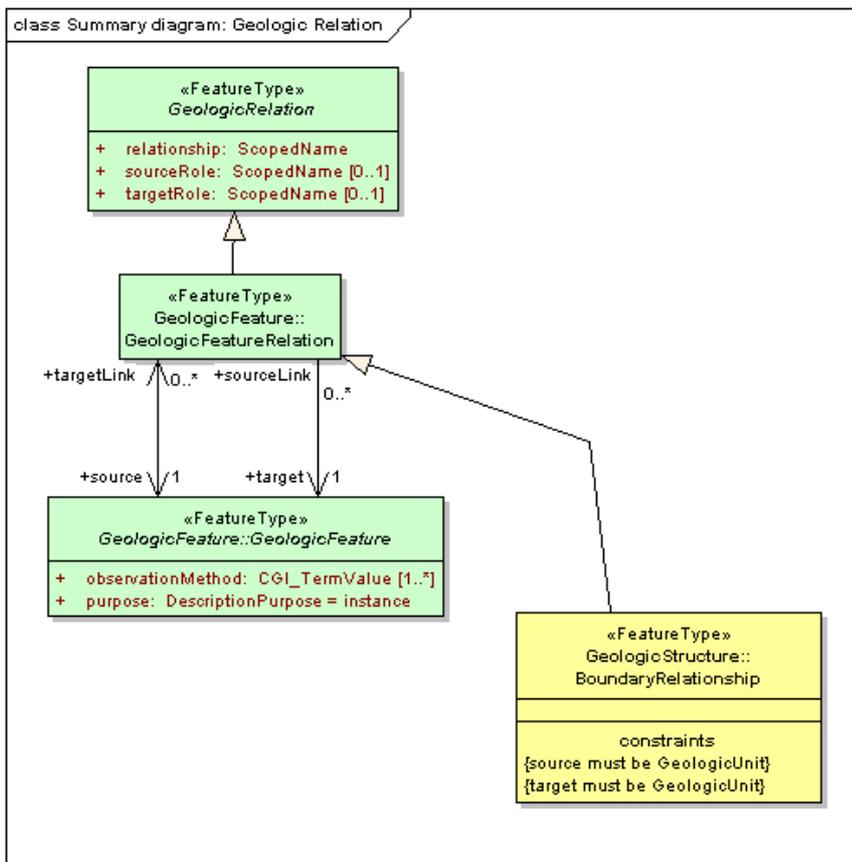


Figure 9: Summary UML diagram for the Geologic Relation package

GeologicRelations are typed, directed associations between geologic objects. They can represent any of a wide variety of relationships that can exist between two or more Features or other entities. GeologicRelations are likely to be of most use where specialisations have been developed.

The GeologicFeatureRelation class is a subtype that is used to define relationships between geologic features, ie. structure-structure, unit-unit, and structure-unit relationships. Appropriate relationship attributes might include: intrudes, overlies, offsets, crosscuts, folds, etc. Both the 'Source' and 'Target' have a role in the relationship. Where an igneous unit intrudes a sedimentary unit, the geological relationship is 'intrudes', the intruded sedimentary unit has the role 'host', and the igneous unit has the role 'intrusion'

A special type of GeologicFeatureRelation is the BoundaryRelationship which defines the two GeologicUnits that bound a Contact (see section 3.2.4).

3.2.9 CGI Values

The CGI_Value package defines two different data types of particular relevance to geoscience: generic values and geometric values.

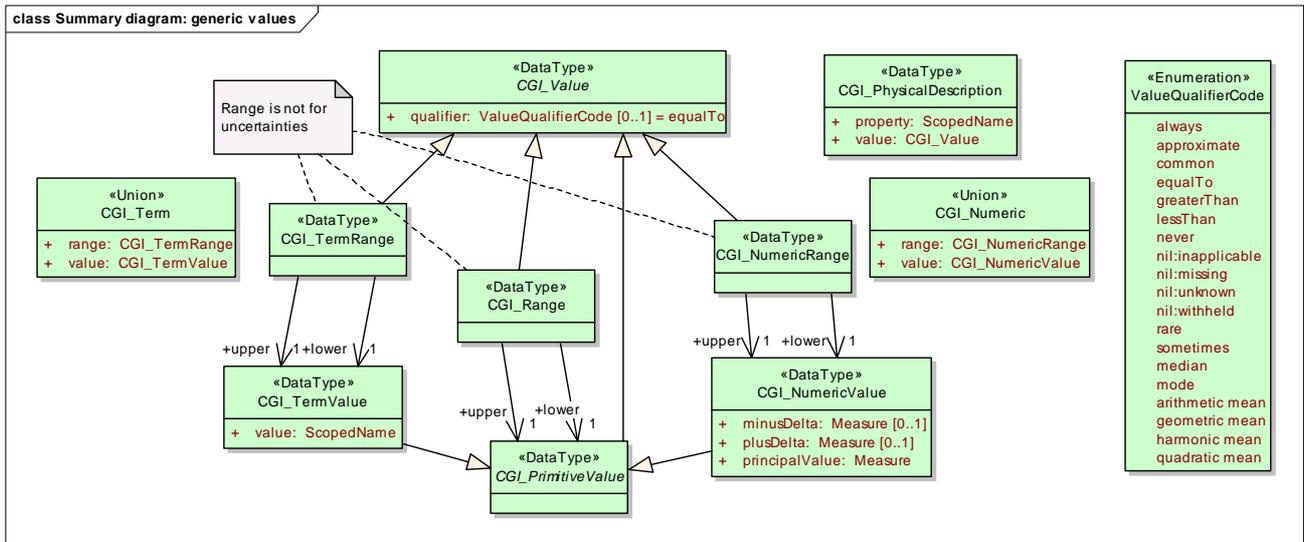


Figure 10: Summary UML diagram for the Generic Values package

The generic values model (Figure 10) provides a way of encoding 'literal' values, both textual and numeric, which have uncertainty and may be a range. These structures are designed to capture value descriptions as conventionally recorded by geologists. They are required if the value you wish to record has a qualifier, such as 'rare' or 'approximate'; where it can be either a single value or a range; where you wish to record the uncertainty of a numeric value; or where a value or range can contain either text or numeric values or a combination of both.

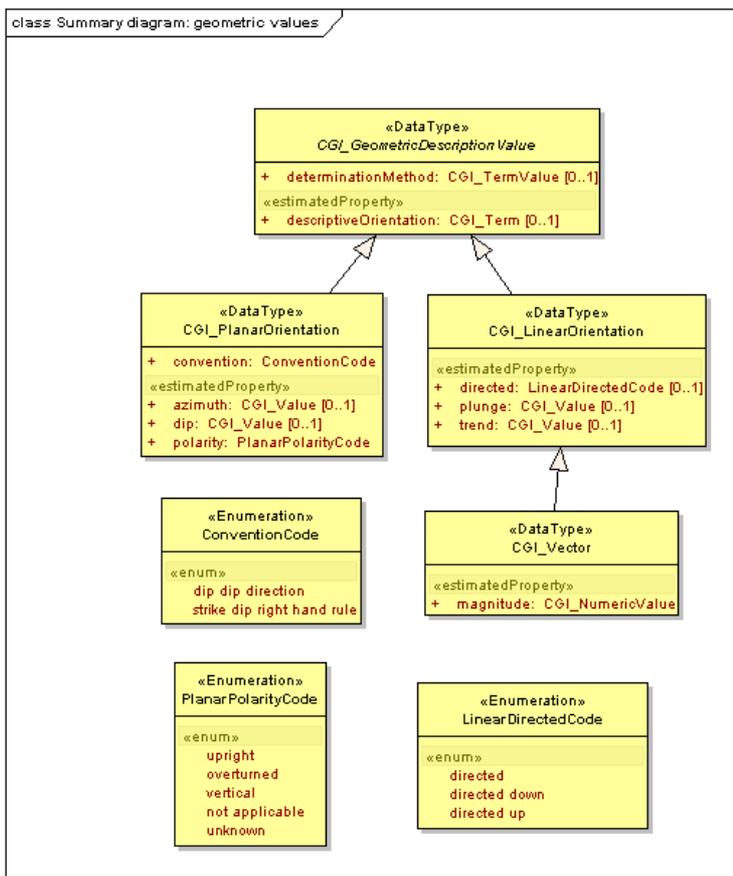


Figure 11: Summary UML diagram for the Geometric Values package

The geometric values model (Figure 11) enables the description of the planar or linear orientation of a GeologicFeature. Geometric values are particularly used in the GeologicStructure package (see section 3.2.4). For PlanarOrientation values differing measurement conventions (eg right hand rule) can be used and recorded, as can the polarity (upright or overturned) of the feature being measured. LinearOrientations may have an orientation in 3D space, described by trend and plunge, along with a direction and magnitude.

3.2.10 Vocabulary

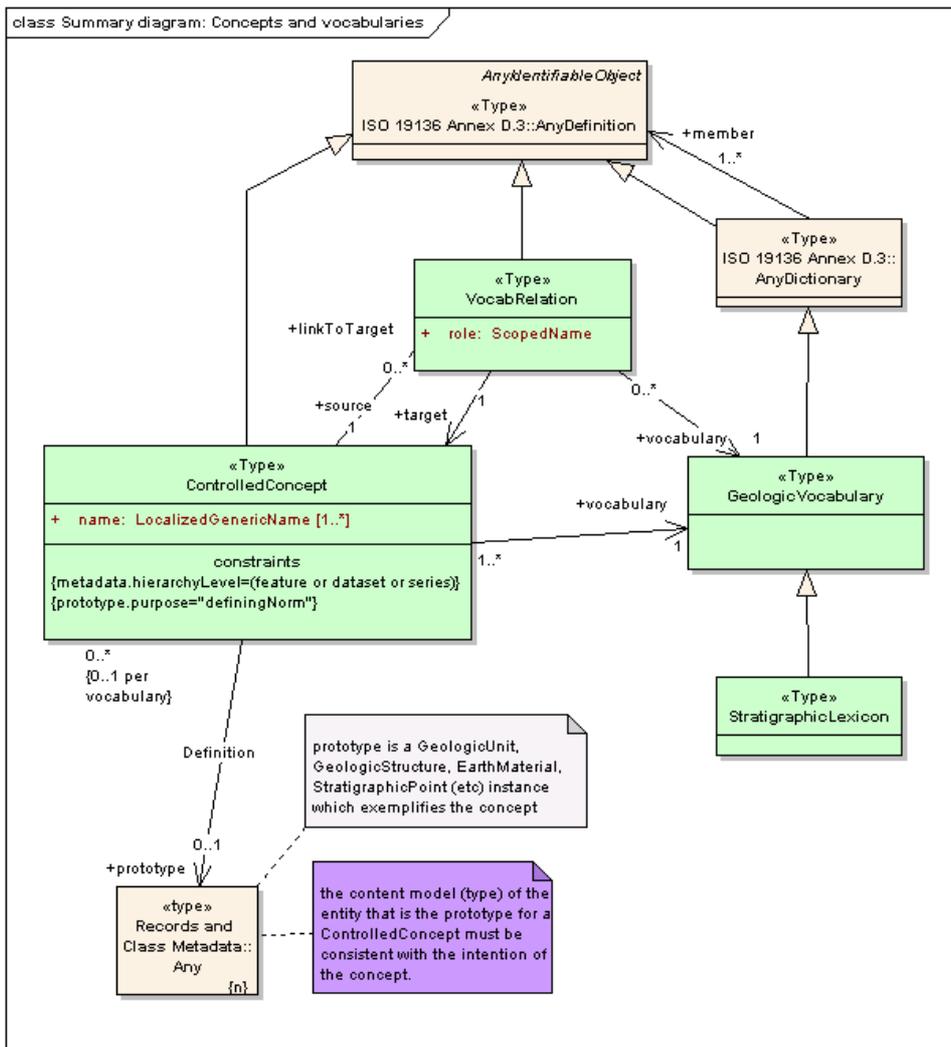


Figure 12: Summary UML diagram for the Vocabulary package

The specification of a GeologicVocabulary is derived as a sub-type from the ISO19136 AnyDictionary definition. A StratigraphicLexicon is defined as a sub-type of GeologicVocabulary. A GeologicVocabulary contains members which may be either ControlledConcepts or VocabRelations.

At its simplest a ControlledConcept will have a name and, commonly, a description. A ControlledConcept can have several names, for example in different languages, and can be defined using a prototype. For example, most geological maps do not have descriptive information about each individual polygon, rather they have a key, usually related to a StratigraphicLexicon, which provides a standard (prototype) definition and description. A prototype can be any type of entity, but most commonly will be a GeologicUnit, GeologicStructure, or EarthMaterial instance which

exemplifies the concept. The type of the entity used as a prototype for a ControlledConcept must be consistent with the intention of the concept. GeologicFeature and EarthMaterial prototype definitions follow the same pattern as described for these feature types in sections 3.2.1 and 3.2.3 above, but the 'purpose' property should be set to 'definingNorm' to distinguish prototype descriptions from instance descriptions.

VocabRelations enable the relationship between ControlledConcepts to be described and can be used to implement thesaurus type relationships like 'broader than', 'narrower than', 'related term', and 'synonym'. The 'role' property specifies the nature of the relationship between the source ControlledConcept and the target ControlledConcept, read as 'source' - 'role' - 'target' (eg metasediment broader than metalimestone).

The Vocabulary package is likely to be replaced at some point by more suitable ontology models, but these are not yet available.

3.2.11 Metadata

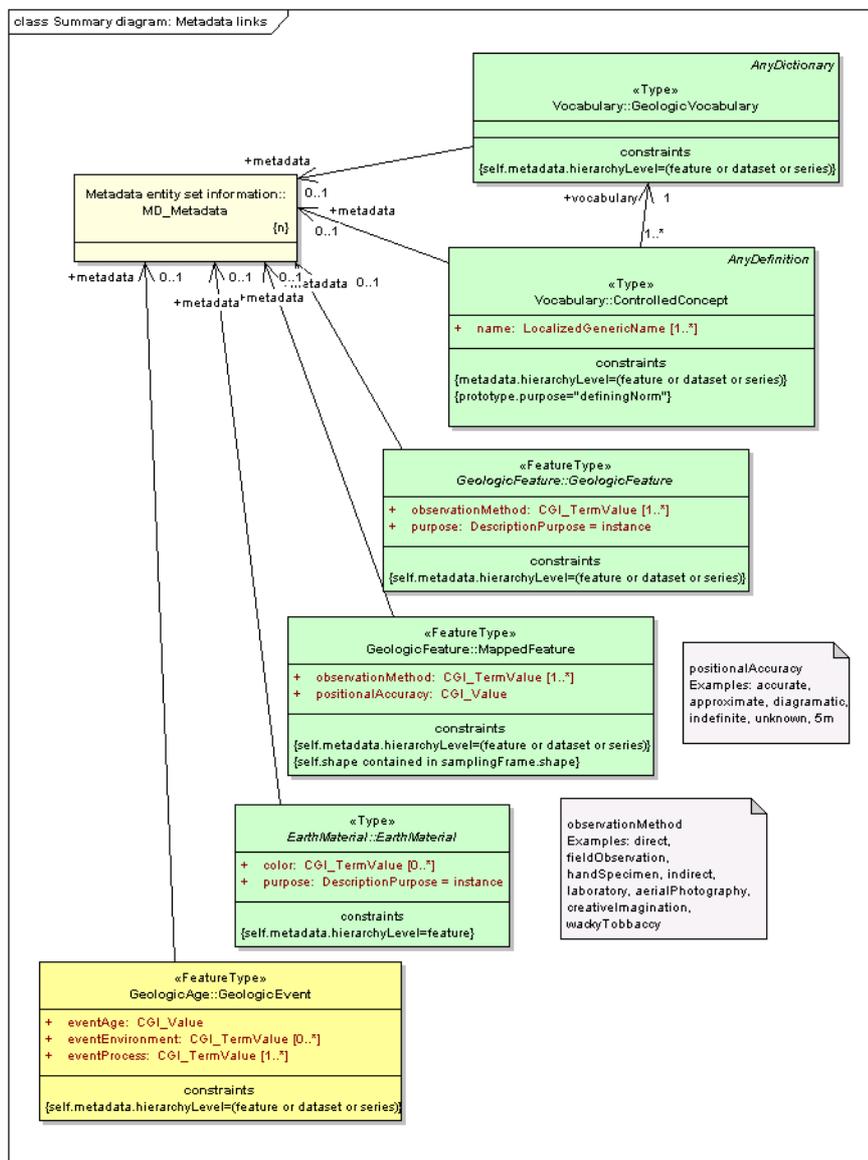


Figure 13: Summary UML diagram for the Metadata package

The GeoSciML Metadata package shows the metadata links from various GeoSciML classes. GeoSciML refers to the (externally maintained) ISO 19115 metadata package (MD_Metadata). Metadata can apply to an individual feature, for example a particular map polygon; a dataset, for example a map sheet; or a series, for example all 1:50k scale bedrock geology maps. Pending GeoSciML migrating to GML v3.2, the XML Schema contains a stub schema representing the actual metadata elements. As well as metadata referring to individual GeoSciML classes, metadata can be provided describing the collection of information being delivered in response to a particular WFS call (see section 3.2.12).

3.2.12 Collection

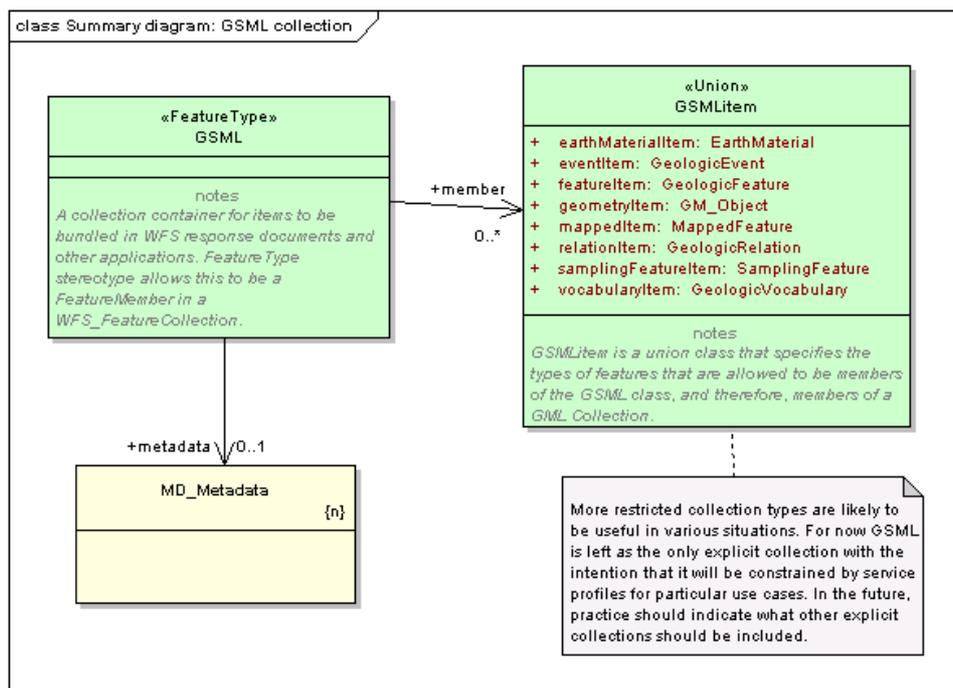


Figure 14: Summary UML diagram for the Collection package

The GSML feature is a container for the information to be sent in response to a WFS request. The GSML container can hold, as members, any of the types of feature in the GSMLItem union class which includes all of the GeoSciML classes. In the future, sub-types of the GSML container may be required to define the scope of information returned in response to particular types of WFS request.

Metadata can be provided about the collection. This is distinct from the metadata describing items within the collection, which is documented in section 3.2.11.

In most cases wfs:FeatureCollection should be used in preference to GSML (see section 4.1). GSML is useful when the collection of information being sent does not comprise features, such as a GeologicVocabulary.

4 GUIDELINES FOR MAPPING DATA TO GEOSCI ML

In this version of the guide the mapping from data to the GeoSciML model will be illustrated using exemplar instance documents produced for GeoSciML Testbed 3.1.

Where a GeoSciML property is mandatory, but no value is available, then the urn identifier of one of the 'nil' values defined by OGC should be used. Information on these is given at <https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/OgcURNScheme>. Alternatively a nil value type may be defined in a user's own vocabulary.

OGC also defines units of measurement and the identifiers for these is also given at <https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/OgcURNScheme>.

4.1 Feature collections

The features being delivered in a GeoSciML document should be bundled into a FeatureCollection. The 2D spatial limits covered by the FeatureCollection, such as the map extent, can also be specified but this is not mandatory. There is no restriction on the contents of a FeatureCollection, other than that they must be features, but it is sensible to restrict a collection to features of one type or closely related types. For example if you wish to deliver both GeologicUnits and GeologicStructures, such as Faults, these would be best sent as separate FeatureCollections, although the details of how data is structured into FeatureCollections will depend on the purpose for which it is being delivered. Figure 15 illustrates a segment from the start of GeoSciML document.

```
<?xml version="1.0" encoding="UTF-8" ?>
- <wfs:FeatureCollection xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.opengis.net/wfs
http://schemas.opengis.net/wfs/1.1.0/wfs.xsd http://www.opengis.net/gml http://schemas.opengis.net/gml/3.1.1/base/gml.xsd
urn:cgi:xmlns:CGI:GeoSciML:2.0 http://www.geosciml.org/schemas/geosciml/2.0_rc3/geosciml.xsd http://www.opengis.net/om/1.0
http://schemas.opengis.net/om/1.0.0/om.xsd http://www.opengis.net/sampling/1.0 http://schemas.opengis.net/sampling/1.0.0/sampling.xsd"
xmlns:gml="http://www.opengis.net/gml" xmlns:wfs="http://www.opengis.net/wfs" xmlns:gsmi="urn:cgi:xmlns:CGI:GeoSciML:2.0"
xmlns:sa="http://www.opengis.net/sampling/1.0" xmlns:om="http://www.opengis.net/om/1.0" xmlns:cgu="urn:cgi:xmlns:CGI:Utilities:1.0"
xmlns:xlink="http://www.w3.org/1999/xlink" gml:id="GA_1M_GeologicUnits_Collection_000001">
- <!--
##### This instance document describes some MappedFeature polygons of three GeologicUnits from the Eastern Australia 1:imillion scale data. #####
##### Geoscience Australia - 14 Oct 2008 #####
-----
-->
- <gml:boundedBy>
- <gml:Envelope srsName="urn:ogc:def:crs:EPSG:4326">
  <gml:lowerCorner>142.17 -18.56</gml:lowerCorner>
  <gml:upperCorner>142.173 -20.56</gml:upperCorner>
</gml:Envelope>
</gml:boundedBy>
- <gml:featureMember>
- <gml:MappedFeature gml:id="GA_1M_geology_polygon_5555">
```

Figure 15: Example of the start of a GeoSciML document

Points to note in Figure 15 are:

- The opening of a wfs:FeatureCollection at the start of the document
- The optional use of gml:boundedBy to specify the 2D spatial limits of the FeatureCollection, along with the spatial reference system (srs) used to define these limits
- All srs's should be specified using an urn giving the European Petroleum Survey Group (EPSG) identifier. These can be found at the EPSG registry at <http://www.epsg-registry.org/>.
- Each feature in the FeatureCollection is a FeatureMember

4.2 Use of names and identifiers

4.2.1 The CGI Identifier Scheme

A web-based service architecture depends on being able to link or otherwise make reference to resources, such as vocabularies or individual items in vocabularies. To this end the CGI has developed an identifier scheme, based on the use of URNs, which is described in detail at <https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/CGIIdentifierScheme>. Some resources are provided and governed by the CGI in support of interoperable services while other resources are maintained by delegated authorities, such as individual geological surveys. For example a simple lithology vocabulary has been developed and made available by the CGI to aid interoperability, but the CGI identifier scheme also allows organisations to reference their own detailed lithology vocabularies. There is an expectation that classifierSchemes, including vocabularies, ontologies and lexicons, and the classifiers within them (an individual concept or vocabulary term) made available through the CGI identifier scheme will be governed by the organisations providing them so that they are a stable resource.

An example of a CGI identifier for the BGS Rock Classification System (RCS) vocabulary is:
urn:cgi:classifierscheme:BGS:RCS.

An example of a CGI identifier for an individual concept (term) within the BGS RCS is:
urn:cgi:classifier:BGS:RCS:METR.

4.2.2 Naming conventions

GeoSciML v2 uses GML v3.1.1 and this provides two properties for identifying and naming items, gml:id and gml:name. However gml:id must be unique within any gml document which makes it an unsuitable property to hold the identifier of items in a GeoSciML document as these identifiers are likely to occur more than once in any document. For example the identifier of a MappedFeature might be the name or code of a lithostratigraphic unit, and there are likely to be several MappedFeatures of the same lithostratigraphic unit within a document. It is therefore recommended that gml:name be used to identify items. Any item can have several gml:names and different gml:names can be used to provide, for example, the full name of a lithostratigraphic unit, the code for the unit, and the lettering used on the map face to identify the unit. In addition gml:id can be used to provide an identifier for cross-referencing within the gml document, but its use should be restricted to this purpose. Figure 16 shows the use of gml:id and gml:name for a GeologicUnit. Note that this example also includes the, optional, use of gml:description to provide a brief human readable description of the item.

```
- <gml:GeologicUnit gml:id="GA_GeologicUnit_Stratno_38485">  
  <gml:description>Channel and flood plain alluvium; gravel, sand, silt, clay</gml:description>  
  <gml:name codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:feature:GA:StratigraphicLexicon:Stratno:38485</gml:name>  
  <gml:name codeSpace="urn:cgi:classifierscheme:GA:StratigraphicLexicon:Stratname">alluvium 38485</gml:name>  
  <gml:name codeSpace="urn:cgi:classifierscheme:GA:StratigraphicLexicon:Map_symbol">Qa</gml:name>
```

Figure 16: Example of the use of names

In the above example the value of the name in the first of the three names is a CGI URN. Where, as in this case, a ScopedName appears in a GeoSciML document whose value is a CGI URN the @codeSpace attribute should be set to '<http://www.cgi-iugs.org/uri>', which directs to the CGI Identifier Resolver managed by BRGM (<http://appgeosci.ml.brgm.fr/GeoSciMLWeb/middleware.jsp>). Where an OGC URN is used then the @codeSpace attribute should be set to '<http://urn.opengis.net>' which directs to the OGC URN resolver.

At present there is no definitive way to encode the object identifier but it is recommended that this format be used for this purpose. In future versions of GeoSciML it is hoped to move to GML v3.2 which provides the property gml:identifier specifically for this purpose.

4.3 Controlled Concepts and Vocabularies

4.3.1 Mapping your own vocabularies

GeoSciML provides a means to encode vocabularies using the model described in section 3.2.10. This model can be used for any type of vocabulary and is illustrated in Figure 17 with a segment of a simple lithology vocabulary.

```
- <GeologicVocabulary xmlns="urn:cgi:xmlns:CGI:GeoSciML:2.0" xmlns:gml="http://www.opengis.net/gml" gml:id="SimpleLithology">
  <gml:name codeSpace="http://www.cgi-iugs.org/uri"urn:cgi:classiferScheme:CGI:SimpleLithology:200811</gml:name>
- <gml:definitionMember type="simple">
- <ControlledConcept gml:id="compound_material">
  <gml:description type="simple">An Earth Material composed of an aggregation of particles of Earth Material, possibly including other Compound
  Materials. This is 'top' of lithology category hierarchy, and should be used to indicate 'any rock or unconsolidated material'. Source: NADM C1,
  2004</gml:description>
  <gml:name>0...</gml:name>
  <gml:name codeSpace="http://www.cgi-iugs.org/uri"urn:cgi:classiferScheme:CGI:SimpleLithology:200811:compound_material</gml:name>
  <name xml:lang="en">Compound material</name>
  <vocabulary xmlns:xlink="http://www.w3.org/1999/xlink" xlink:href="urn:cgi:classiferScheme:CGI:SimpleLithology:200811" type="simple" />
</ControlledConcept>
</gml:definitionMember>
- <gml:definitionMember type="simple">
- <ControlledConcept gml:id="breccia">
  <gml:description type="simple">Coarse-grained material composed of angular broken rock fragments; the fragments typically have sharp edges and
  unworn corners. The fragments may be held together by a mineral cement, or in a fine-grained matrix. Clasts may be of any composition or
  origin. Source: Neuendorf et al. 2005</gml:description>
  <gml:name>1...</gml:name>
  <gml:name codeSpace="http://www.cgi-iugs.org/uri"urn:cgi:classiferScheme:CGI:SimpleLithology:200811:breccia</gml:name>
  <name xml:lang="en">Breccia</name>
  <vocabulary xmlns:xlink="http://www.w3.org/1999/xlink" xlink:href="urn:cgi:classiferScheme:CGI:SimpleLithology:200811" type="simple" />
- <linkToTarget type="simple">
- <VocabRelation gml:id="rel_SimpleLithology_2">
  <gml:name>rel_SimpleLithology_2</gml:name>
  <role codeSpace="urn:cgi:classiferScheme:CGI:VocabRelationRoles:2008">Broader term</role>
  <source xmlns:xlink="http://www.w3.org/1999/xlink" xlink:href="urn:cgi:classiferScheme:CGI:SimpleLithology:200811:breccia"
  type="simple" />
  <target xmlns:xlink="http://www.w3.org/1999/xlink" xlink:href="urn:cgi:classiferScheme:CGI:SimpleLithology:200811:compound_material"
  type="simple" />
  <vocabulary xmlns:xlink="http://www.w3.org/1999/xlink" xlink:href="urn:cgi:classiferScheme:CGI:SimpleLithology:200811" type="simple" />
</VocabRelation>
</linkToTarget>
</ControlledConcept>
</gml:definitionMember>
```

Figure 17: Example of a 'simple' lithology vocabulary

Points to note in Figure 17 are:

- The gml:id of the GeologicVocabulary is mandatory but must be unique within any document. This limits its value as an identifier and it is up to the data provider to decide what value to put here
- The gml:name of the GeologicVocabulary provides the urn of the vocabulary. Vocabularies should be registered in the GeoSciML vocabulary registry at <http://appgeosciml.brgm.fr/GeoSciMLWeb/>
- A gml:name of the ControlledConcept should provide the urn of the concept
- The gsml:name(s) should be used to provide the name of the ControlledConcept in the language in which it was defined, and in other languages as defined by the xml:lang attribute
- The gml:description of the ControlledConcept can be used to provide an expanded description or definition of the concept
- VocabRelation is used to define the relationship between ControlledConcepts
- VocabularyRelations read source->role->target, in this case breccia->Broader term->compound_material
- Role terms should ideally be drawn from the CGI VocabularyRelation vocabulary. In this example 'Broader term' is defined as 'link from a source term to a superordinate (more general

or parent) target term'. Therefore the VocabRelation is stating that compound_material is a superordinate term to breccia

As well as the simple vocabulary pattern described above it is possible to define ControlledConcepts using prototypes, as described in section 3.2.10. This is illustrated in figure 18 with an example of a lithology vocabulary using prototypes.

```
<?xml version="1.0" encoding="UTF-8" ?>
<!-- GSV's alternative to the example of Earth Material vocabulary from BGS Rock Classification System. -->
- <gsml:GSML xmlns="urn:cgi:xmlns:CGI:GeoSciML:2.0" xmlns:gsml="urn:cgi:xmlns:CGI:GeoSciML:2.0" xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:gml="http://www.opengis.net/gml" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="urn:cgi:xmlns:CGI:GeoSciML:2.0
  http://geosciml.org/geosciml/2.0/xsd/geosciml.xsd">
- <!--
  The start of the vocabulary. The urns and names of the lithologies are given in the ControlledConcepts. I have used internal
  document referencing in the xlink of the prototype as the prototype definition is an integral part of the ControlledConcept
  and must therefore be in the document. The vocabulary contains VocabularyRelations defining the relationship between the
  ControlledConcept lithology terms
-->
- <gsml:member>
- <gsml:GeologicVocabulary gml:id="RCS">
  <gml:name codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:classifer:BGS:RCS</gml:name>
- <gml:definitionMember>
- <gsml:ControlledConcept gml:id="RCS1">
  <gml:name codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:classifer:BGS:RCS:METR</gml:name>
  <gml:name xml:lang="en" codeSpace="urn:cgi:classiferScheme:BGS:RCS">METAMORPHIC ROCK</gml:name>
  <gsml:vocabulary xlink:href="urn:cgi:classiferScheme:BGS:RCS" />
- <gsml:prototype>
- <gsml:RockMaterial gml:id="ROCK1">
  <gml:purpose>definingNorm</gml:purpose>
- <gsml:geneticCategory>
- <gsml:CGI_TermValue>
  <gml:value codeSpace="urn:cgi:classiferScheme:BGS:geneticCatTerms">METAMORPHIC</gml:value>
  </gml:CGI_TermValue>
  </gml:geneticCategory>
- <gsml:consolidationDegree>
- <gsml:CGI_TermValue>
  <gml:value codeSpace="urn:cgi:classiferScheme:BGS:consolidationTerms">INDURATED</gml:value>
  </gml:CGI_TermValue>
  </gml:consolidationDegree>
  <gsml:lithology xlink:href="urn:cgi:classifer:BGS:RCS:METR" />
  </gml:RockMaterial>
  </gml:prototype>
  </gml:ControlledConcept>
</gml:definitionMember>
```

Figure 18: Example of lithology vocabulary using prototypes

Points to note in Figure 18 are:

- This example shows the first ControlledConcept in a vocabulary, and uses an inline prototype definition
- Prototypes can be of any type of entity but they must be consistent with the ControlledConcept of which they are the prototype. So, for example, a StratigraphicLexicon vocabulary would normally be defined by a GeologicUnit prototype, where geologicUnitType is 'Lithostratigraphic'. The example in Figure 18 is of a lithology vocabulary which is defined by a RockMaterial prototype
- In the RockMaterial example in Figure 18 there is a circularity. RockMaterial has a mandatory lithology property, which in the case of a RockMaterial prototype such as this, points to the ControlledConcept being defined by the RockMaterial prototype. Future versions of the model will address this problem

Note that any vocabularies referenced in GeoSciML should, ideally, both be identified using the CGI identifier scheme, as described in section 4.1.1, and be made available through the GeoSciML registry at <http://appgeosciml.brgm.fr/GeoSciMLWeb/>.

4.3.2 CGI supported common vocabularies

When an organisation wishes to use GeoSciML to deliver its data to an external organisation it will normally wish to reference its own vocabularies, as these will have been used to describe the data in the organisation's internal databases and their use will therefore capture the full richness of the

original information. However, the use of an organisation's own vocabularies limits interoperability. Different organisations may be providing data using GeoSciML, which will therefore be structured in the same way, but if each is using its own ControlledConcepts and vocabularies then there is no semantic interoperability between them.

To address this problem a set of common vocabularies, containing shared ControlledConcepts, has been set up. The available vocabularies can be viewed in the GeoSciML registry at <http://appgeosciml.brgm.fr/GeoSciMLWeb/> and will be added to as required.

4.4 The delivery of mapped geological units

The delivery of geological map information is central to the purpose of GeoSciML. The principal component of most geologic maps are the polygons delimiting the extent of particular geologic units and there are two ways that these can be delivered, as MappedFeatures specified by GeologicUnits (see section 3.2.1) or as GeologicUnits with optional occurrences (see section 3.2.2).

4.4.1 *The delivery of MappedFeatures*

The delivery of MappedFeatures is the approach which relates most closely to a geologic map and therefore the approach that is likely to be most commonly used. Each MappedFeature describes a single polygon on the geologic map (or potentially a single surface or volume in a geologic model), providing information about both its shape and the GeologicFeature specification that determines what the MappedFeature is.

Figure 19 illustrates part of a GeoSciML document containing a collection of MappedFeatures specified by GeologicUnit.

```

- <gml:featureMember>
- <gml:MappedFeature gml:id="GA_1M_geology_polygon_11462">
- <gml:observationMethod>
- <gml:CGI_TermValue>
  <gml:value codeSpace="urn:cgi:classiferScheme:GA:1MillionGeology_ObservationMethods">Smout, J., Grimes, K.G., Poutch, H.F., Swoboda, R.A., Russell, E.A.,
  Carpentaria and Karumba Basins 1:1,000,000, Geological Survey of Queensland & Bureau of Mineral Resources.</gml:value>
</gml:CGI_TermValue>
</gml:observationMethod>
- <gml:positionalAccuracy>
- <gml:CGI_NumericValue>
  <gml:principalValue uom="urn:ogc:def:uom:UCUM:m">1500</gml:principalValue>
</gml:CGI_NumericValue>
</gml:positionalAccuracy>
<gml:samplingFrame xlink:href="urn:cgi:feature:CGI:EarthNaturalSurface" />
- <gml:specification>
- <gml:GeologicUnit gml:id="GA_GeologicUnit_Stratno_38484">
  <gml:description>Quaternary sediments, undivided</gml:description>
  <gml:name codeSpace="urn:cgi:classiferScheme:GA:StratigraphicLexicon:Stratname">sediments 38484</gml:name>
  <gml:name codeSpace="urn:cgi:classiferScheme:GA:StratigraphicLexicon:Map_symbol">Qs</gml:name>
  <gml:name codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:feature:GA:StratigraphicLexicon:Stratno:38484</gml:name>
- <gml:observationMethod>
- <gml:CGI_TermValue>
  <gml:value codeSpace="urn:cgi:classiferScheme:GA:ObservationMethods">published description</gml:value>
</gml:CGI_TermValue>
</gml:observationMethod>
<gml:purpose>typicalNorm</gml:purpose>
- <gml:preferredAge>
- <gml:GeologicEvent>
- <gml:eventAge>
- <gml:CGI_TermRange>
- <gml:lower>
- <gml:CGI_TermValue>
  <gml:value codeSpace="urn:cgi:classiferScheme:ICS:StratChart:2008">urn:cgi:classifer:ICS:StratChart:2008:Quaternary</gml:value>
</gml:CGI_TermValue>
</gml:lower>
- <gml:upper>
- <gml:CGI_TermValue>
  <gml:value codeSpace="urn:cgi:classiferScheme:ICS:StratChart:2008">urn:cgi:classifer:ICS:StratChart:2008:Quaternary</gml:value>
</gml:CGI_TermValue>
</gml:upper>
</gml:CGI_TermRange>
</gml:eventAge>
- <gml:eventProcess>
- <gml:CGI_TermValue>
  <gml:value codeSpace="urn:cgi:classiferScheme:GA:Process">deposition</gml:value>
</gml:CGI_TermValue>
</gml:eventProcess>
</gml:GeologicEvent>
</gml:preferredAge>
<gml:geologicUnitType xlink:href="#Lithostratigraphic_Unit" />
- <gml:compositionCategory>
- <gml:CGI_TermValue>
  <gml:value codeSpace="urn:cgi:classiferScheme:GA:CompositionCategory">unknown</gml:value>
</gml:CGI_TermValue>
</gml:compositionCategory>
<gml:rank codeSpace="urn:cgi:classiferScheme:GA:Rank">formation</gml:rank>
<gml:classifer xlink:href="urn:cgi:classifer:GA:StratigraphicLexicon:Stratno:38484" />
</gml:GeologicUnit>
</gml:specification>
- <gml:shape>
- <gml:Polygon srsName="urn:ogc:def:crs:EPSG:4326">
- <gml:outerBoundaryIs>
- <gml:LinearRing>
  <gml:posList>142.177639798951 -19.2583990608557 142.172068544096 -19.2546485090388 142.155416913158 -19.2516959832536 142.141116191144 -
  19.2449615283995 142.136385949755 -19.2457329336206 142.136395566884 -19.2479970732439 142.140372291732 -19.2517521359808 142.15384938
  19.2577358051352 142.168928361458 -19.2599404653786 142.172899243883 -19.2621870745973 142.176062814743 -19.262174894991 142.177639798
  19.2583990608557</gml:posList>
</gml:LinearRing>
</gml:outerBoundaryIs>
</gml:Polygon>
</gml:shape>
</gml:MappedFeature>
</gml:featureMember>
- <gml:featureMember>
- <gml:MappedFeature gml:id="GA_1M_geology_polygon_11341">
- <gml:observationMethod>
- <gml:CGI_TermValue>
  <gml:value codeSpace="urn:cgi:classiferScheme:GA:1MillionGeology_ObservationMethods">Smout, J., Grimes, K.G., Poutch, H.F., Swoboda, R.A., Russell, E.A., 19
  Carpentaria and Karumba Basins 1:1,000,000, Geological Survey of Queensland & Bureau of Mineral Resources.</gml:value>
</gml:CGI_TermValue>
</gml:observationMethod>
- <gml:positionalAccuracy>
- <gml:CGI_NumericValue>
  <gml:principalValue uom="urn:ogc:def:uom:UCUM:m">1500</gml:principalValue>
</gml:CGI_NumericValue>
</gml:positionalAccuracy>
<gml:samplingFrame xlink:href="urn:cgi:feature:CGI:EarthNaturalSurface" />
<gml:specification xlink:href="#GA_GeologicUnit_Stratno_38484" />
- <gml:shape>
- <gml:Polygon srsName="urn:ogc:def:crs:EPSG:4326">
- <gml:outerBoundaryIs>
- <gml:LinearRing>
  <gml:posList>142.213110178538 -19.2205518057331 142.205966387869 -19.2160542100034 142.179787766919 -19.2093689425853 142.164716518787 -
  19.2026408667063 142.161532761034 -19.2034070041275 142.163939693161 -19.2071678093696 142.176648483254 -19.2146613609424 142.20837070
  19.2243406910478 142.210761360764 -19.2243311133382 142.213110178538 -19.2205518057331</gml:posList>
</gml:LinearRing>
</gml:outerBoundaryIs>
</gml:Polygon>
</gml:shape>
</gml:MappedFeature>
</gml:featureMember>

```

Figure 19: Example of MappedFeatures specified by GeologicUnit

Points to note in Figure 19 are:

- There is an observationMethod property for both the MappedFeature and GeologicUnit. MappedFeature observationMethod indicates how the spatial extent of the MappedFeature was determined, and the basis for the association of the geometry with some GeologicFeature specification. GeologicFeature observationMethod specifies the approach to acquiring the attribute values for the feature instance
- The units of measurement for positionalAccuracy (metres) is defined using the OGC URN urn:ogc:def:uom:UCUM:m
- The samplingFrame will usually be the topographic surface or the bedrock surface for geological maps
- In most cases geological maps do not provide local observational information specific to individual polygons, rather they describe the mapped polygons by reference to a map key. The GeologicUnits specifying the MappedFeatures are therefore normative descriptions, commonly drawn from a StratigraphicLexicon. The purpose property should therefore be either definingNorm or typicalNorm
- In this example the two MappedFeatures given are specified by the same GeologicUnit. For the first MappedFeature the specifying GeologicUnit is given in-line, while for the second the specification is given by reference to the first (using gml:id)
- It is not mandatory to provide a preferredAge, as this may be provided in the StratigraphicLexicon used to classify the GeologicUnit
- The encoding of eventAge is very flexible, allowing any type of CGI_Value (terms and numeric, values and ranges). In this example a range of age terms has been used
- Age terms should use the ICS Statigraphic Chart available at <http://www.stratigraphy.org/>
- The geologicUnitType property is mandatory and is 'byReference', so that it must be set to a value from a defined vocabulary. In order to maximise interoperability it is strongly recommended that the CGI GeologicUnitType vocabulary be used.
- In this example both compositionCategory and rank are encoded, although these are not mandatory. Rank information will commonly be provided by a StratigraphicLexicon
- The classifier is not mandatory but should normally be populated for GeologicUnits from a geologic map. The classifier would typically reference a ControlledConcept in the StratigraphicLexicon of the organisation providing the data, and this StratigraphicLexicon vocabulary should ideally be registered in the GeoSciML vocabulary registry
- The ControlledConcepts used to classify a GeologicUnit may be defined using prototype GeologicUnits (see section 4.3.1). These prototype descriptions may have values for properties, such as preferredAge or composition, which are also given in the description of the GeologicUnit being classified. In this case the values of properties in the GeologicUnit should lie within the semantic range defined in the prototype and should be seen as providing more specific values

For some applications it will be necessary to provide information about the relationship between GeologicUnits and this can be done using the optional GeologicFeatureRelation feature. Figure 20 gives an example of the use of this.

```

- <gsml:targetLink>
- <gsml:GeologicFeatureRelation gml:id="gfr.1000000000638460000">
  <gsml:relationship codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationship">overlying</gsml:relationship>
  <gsml:sourceRole codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationshipRole">overlies [overlying]</gsml:sourceRole>
  <gsml:targetRole codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationshipRole">underlies [overlying]</gsml:targetRole>
  <gsml:target xlink:href="urn:cgi:feature:GSV:TestBedUID:26937119" />
  <gsml:source xlink:href="urn:cgi:feature:GSV:TestBedUID:26930665" />
</gsml:GeologicFeatureRelation>
</gsml:targetLink>
- <gsml:targetLink>
- <gsml:GeologicFeatureRelation gml:id="gfr.1000000000725040000">
  <gsml:relationship codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationship">overlying</gsml:relationship>
  <gsml:sourceRole codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationshipRole">overlies [overlying]</gsml:sourceRole>
  <gsml:targetRole codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationshipRole">underlies [overlying]</gsml:targetRole>
  <gsml:target xlink:href="urn:cgi:feature:GSV:TestBedUID:26931158" />
  <gsml:source xlink:href="urn:cgi:feature:GSV:TestBedUID:26930665" />
</gsml:GeologicFeatureRelation>
</gsml:targetLink>
- <gsml:targetLink>
- <gsml:GeologicFeatureRelation gml:id="gfr.1000000000755920000">
  <gsml:relationship codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationship">onlapping</gsml:relationship>
  <gsml:sourceRole codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationshipRole">onlaps</gsml:sourceRole>
  <gsml:targetRole codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationshipRole">onlapped</gsml:targetRole>
  <gsml:target xlink:href="urn:cgi:feature:GSV:TestBedUID:26937154" />
  <gsml:source xlink:href="urn:cgi:feature:GSV:TestBedUID:26930665" />
</gsml:GeologicFeatureRelation>
</gsml:targetLink>
- <gsml:targetLink>
- <gsml:GeologicFeatureRelation gml:id="gfr.1000000000831920000">
  <gsml:relationship codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationship">onlapping</gsml:relationship>
  <gsml:sourceRole codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationshipRole">onlaps</gsml:sourceRole>
  <gsml:targetRole codeSpace="urn:cgi:classiferScheme:GSV:StratigraphicRelationshipRole">onlapped</gsml:targetRole>
  <gsml:target xlink:href="urn:cgi:feature:GSV:TestBedUID:26931529" />
  <gsml:source xlink:href="urn:cgi:feature:GSV:TestBedUID:26930665" />
</gsml:GeologicFeatureRelation>
</gsml:targetLink>

```

Figure 20: Example of encoding of GeologicFeatureRelation

Points to note from Figure 20 are:

- This GeologicFeatureRelation description is from the description of GeologicUnit urn:cgi:feature:GSV:TestBedUID:26930665, and describes the relationship between this GeologicUnit and others
- The GeologicUnit being described is the source of the GeologicFeatureRelation
- The relationship property is mandatory and reads from source to target, so that in the first GeologicFeatureRelation in Figure 20 urn:cgi:feature:GSV:TestBedUID:26930665 is overlying urn:cgi:feature:GSV:TestBedUID:26937119

4.4.2 The delivery of GeologicUnits

This approach involves delivering a list of GeologicUnits without the spatial information defining the extent of the GeologicUnits, for example in response to a question such as ‘give me all the GeologicUnits which are found within a (defined) area’. An extension of this approach does provide the spatial information, but by reference to GeologicUnits, in response to a question such as ‘give me all information about GeologicUnit XYZ including all its occurrences (where it occurs)’. Figure 21 is an example of encoding GeologicUnits with occurrences.

```

<?xml version="1.0" encoding="UTF-8" ?>
- <wfs:FeatureCollection xmlns:gsml="urn:cgi:xmlns:CGI:GeoSciML:2.0" xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:wfs="http://www.opengis.net/wfs"
  numberOfFeatures="2" xsi:schemaLocation="http://www.opengis.net/wfs http://schemas.opengis.net/wfs/1.1.0/wfs.xsd urn:cgi:xmlns:CGI:GeoSciML:2.0
  http://www.geosciml.org/geosciml/2.0/xsd/geosciml.xsd" >
- <gml:featureMember>
- <gsml:GeologicUnit gml:id="gu.26932776">
  <gml:description>Undifferentiated: sandstone, siltstone, black shale; sparsely fossiliferous</gml:description>
  <gml:name codeSpace="http://www.gsv-tb.dpi.vic.gov.au/geosciml-testbed3/tb3.1/wfs">urn:cgi:feature:GSV:TestBedUID:26932776</gml:name>
  <gml:name codeSpace="urn:cgi:classiferScheme:GSV:GeologicalUnitCode">Oc</gml:name>
  <gml:name codeSpace="urn:cgi:classiferScheme:GSV:GeologicalUnitName">Castlemaine Group</gml:name>
- <gsml:observationMethod>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="http://urn.opengis.net">urn:ogc:def:nil:OGC:missing</gsml:value>
  </gsml:CGI_TermValue>
  </gsml:observationMethod>
  <gsml:purpose>typicalNorm</gsml:purpose>
- <gsml:occurrence>
- <gsml:MappedFeature gml:id="mf.25198">
  <gsml:observationMethod>
  <gsml:CGI_TermValue>
    <gsml:value codeSpace="http://urn.opengis.net">urn:ogc:def:nil:OGC:missing</gsml:value>
    </gsml:CGI_TermValue>
  </gsml:observationMethod>
- <gsml:positionalAccuracy>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="http://urn.opengis.net">urn:ogc:def:nil:OGC:missing</gsml:value>
  </gsml:CGI_TermValue>
  </gsml:positionalAccuracy>
  <gsml:samplingFrame xlink:href="urn:cgi:feature:CGI:EarthNaturalSurface" />
  <gsml:specification xlink:href="#gu.26932776" />
- <gsml:shape>
- <gml:Polygon srsName="EPSG:4326">
  <gml:exterior>
  <gml:LinearRing>
    <gml:posList srsDimension="2">144.52133803333345 -37.46897784166656 144.52135063333344 -37.468987816666555
    144.5214262750001 -37.46920497499989 144.5213583666668 -37.469442358333225 144.52129110833343
    37.46967074166656 144.5211407750001 -37.46987935833322 144.5211685500001 -37.47011874166656 144.52122113333346 -
    .....
    144.51958371666677 -37.46955829166656 144.51986218333343 -37.46946050833323 144.52010566666678 -
    37.46933044166656 144.52029099166677 -37.46915410833323 144.52050000833344 -37.46898728333323
    144.52078988333344 -37.46890775833322 144.5210955250001 -37.46889614999989 144.52133803333345 -
    37.46897784166656</gml:posList>
  </gml:LinearRing>
  </gml:exterior>
  </gml:Polygon>
  </gsml:shape>
  </gsml:MappedFeature>
</gsml:occurrence>

```

Figure 21: Example of encoding GeologicUnits with occurrences

Points to note in Figure 21 are:

- The encoding rules for GeologicUnits are the same whether the GeologicUnits are specifying MappedFeatures, as described in section 4.4.1, or being delivered directly as illustrated here
- The use of the occurrence property to identify a MappedFeature polygon delimiting an area of occurrence of the GeologicUnit
- A GeologicUnit is likely to have many occurrences
- The use of urn:ogc:def:nil:OGC:missing to define a missing value for the mandatory observationMethod property

4.5 How to describe lithologies

The lithology of GeologicUnits is described using the optional composition association to CompositionPart (see section 3.2.2). Some GeologicUnits will have a single composition, but others may have multiple compositions, such as interbedded layers, the composition of each of which can be described.

CompositionPart has a mandatory lithology property for allocating a single lithological term, such as 'sandstone', to the CompositionPart. These terms would normally reference ControlledConcepts in a lithology vocabulary, which could in turn be defined with CompoundMaterial prototypes. Multiple lithology terms can be provided for a single CompositionPart, but this is to enable terms from different vocabularies (for example using chemical or genetic classifications) to be used, not to allow multiple terms from the same vocabulary.

Where more complex lithological descriptions are required the optional material property should be used which allows a full CompoundMaterial description (see section 3.2.3) to be given.

Figure 22 is an example of a simple lithology encoding.

```
- <gsml:composition>
- <gsml:CompositionPart>
  <gsml:role codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:classifier:CGI:GeologicUnitPartRole:only_part</gsml:role>
  <gsml:lithology xlink:href="urn:cgi:classifier:CGI:SimpleLithology:2008:Sandstone" />
- <gsml:proportion>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:classifier:CGI:ProportionTerm:2008:all</gsml:value>
  </gsml:CGI_TermValue>
</gsml:proportion>
</gsml:CompositionPart>
</gsml:composition>
```

Figure 22: Example of a simple lithology encoding

Points to note from Figure 22 are:

- The role property describes the role of the CompositionPart in the overall composition.
- Where there is only a single CompositionPart in the composition, as in this case, then the role should be 'only_part'.
- It is recommended that the CGI GeologicUnitPartRole vocabulary be used for role terms
- In this example the lithology property references a term in the CGI SimpleLithology vocabulary. Terms from a data provider's own vocabulary could be referenced here instead.
- The proportion property indicates the proportion the CompositionPart forms of the overall composition. It can be given either as a term value, as in this example, or as a numeric value (such as a percentage).
- It is recommended that where terms are used they reference the CGI ProportionTerm vocabulary
- It is recommended that proportion terms be used unless the proportion has been measured, in which case a numeric (percentage) value should be given

Figure 23 shows a more complex lithological encoding in which the material property is used.

```
- <gsml:composition>
- <gsml:CompositionPart>
  <gsml:role codeSpace="urn:cgi:classifierScheme:GSV:CompositionpartRole">sole component</gsml:role>
  <gsml:lithology xlink:href="urn:cgi:classifier:CGI:SimpleLithology:2008:amphibolite" />
- <gsml:material>
- <gsml:RockMaterial>
  <gsml:purpose>typicalNorm</gsml:purpose>
- <gsml:consolidationDegree>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="urn:cgi:classifierScheme:GSV:ConsolidationDegree">indurated</gsml:value>
  </gsml:CGI_TermValue>
</gsml:consolidationDegree>
  <gsml:lithology xlink:href="urn:cgi:classifier:CGI:SimpleLithology:2008:amphibolite" />
</gsml:RockMaterial>
</gsml:material>
- <gsml:proportion>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="urn:cgi:classifierScheme:GSV:Proportion">all</gsml:value>
  </gsml:CGI_TermValue>
</gsml:proportion>
</gsml:CompositionPart>
</gsml:composition>
```

Figure 23: Example of lithology encoding using the material property

Points to note from Figure 23:

- The lithology property is encoded in the same way as for simple lithology encoding
- The material property allows a full RockMaterial description to be entered. In this example only the few mandatory RockMaterial properties have been entered, but the model (see section 3.2.3) allows many more
- The lithology property within the RockMaterial description duplicates the lithology property within CompositionPart. This arises as RockMaterial is not only used within the context of CompositionPart

The EarthMaterial package allows RockMaterials to be described in terms of ConstituentParts, thus allowing the description of complex rock types. Figure 24 shows the description of a 'Metalimestone with bands of Calcsilicate rock'.

```

<gsml:RockMaterial gml:id="ROCK5">
  <gsml:purpose>definingNorm</gsml:purpose>
  - <gsml:geneticCategory>
    - <gsml:CGI_TermValue>
      <gsml:value codeSpace="urn:cgi:classiferScheme:BGS:geneticCatTerms">METAMORPHIC</gsml:value>
    </gsml:CGI_TermValue>
  </gsml:geneticCategory>
  - <gsml:part>
    - <gsml:ConstituentPart>
      - <gsml:proportion>
        - <gsml:CGI_TermValue>
          <gsml:value codeSpace="urn:cgi:classiferScheme:BGS:proportionTerms">DOMINANT LITHOLOGY</gsml:value>
        </gsml:CGI_TermValue>
      </gsml:proportion>
      <gsml:role codeSpace="urn:cgi:classiferScheme:BGS:constituentRoleTerms">FRAMEWORK</gsml:role>
    - <gsml:material>
      - <gsml:RockMaterial>
        <gsml:purpose>definingNorm</gsml:purpose>
        - <gsml:geneticCategory>
          - <gsml:CGI_TermValue>
            <gsml:value codeSpace="urn:cgi:classiferScheme:BGS:geneticCatTerms">METAMORPHIC</gsml:value>
          </gsml:CGI_TermValue>
        </gsml:geneticCategory>
        - <gsml:consolidationDegree>
          - <gsml:CGI_TermValue>
            <gsml:value codeSpace="urn:cgi:classiferScheme:BGS:consolidationTerms">INDURATED</gsml:value>
          </gsml:CGI_TermValue>
        </gsml:consolidationDegree>
        <gsml:lithology xlink:href="urn:cgi:classifer:BGS:RCS:MLMST" />
      </gsml:RockMaterial>
    </gsml:material>
  </gsml:ConstituentPart>
</gsml:part>
- <gsml:part>
  - <gsml:ConstituentPart>
    - <gsml:proportion>
      - <gsml:CGI_TermValue>
        <gsml:value codeSpace="urn:cgi:classiferScheme:BGS:proportionTerms">SUBSIDIARY LITHOLOGY</gsml:value>
      </gsml:CGI_TermValue>
    </gsml:proportion>
    <gsml:role codeSpace="urn:cgi:classiferScheme:BGS:constituentRoleTerms">BANDS</gsml:role>
  - <gsml:material>
    - <gsml:RockMaterial>
      <gsml:purpose>definingNorm</gsml:purpose>
      - <gsml:geneticCategory>
        - <gsml:CGI_TermValue>
          <gsml:value codeSpace="urn:cgi:classiferScheme:BGS:geneticCatTerms">METAMORPHIC</gsml:value>
        </gsml:CGI_TermValue>
      </gsml:geneticCategory>
      - <gsml:consolidationDegree>
        - <gsml:CGI_TermValue>
          <gsml:value codeSpace="urn:cgi:classiferScheme:BGS:consolidationTerms">INDURATED</gsml:value>
        </gsml:CGI_TermValue>
      </gsml:consolidationDegree>
      <gsml:lithology xlink:href="urn:cgi:classifer:BGS:RCS:CALSTR" />
    </gsml:RockMaterial>
  </gsml:material>
</gsml:ConstituentPart>
</gsml:part>
- <gsml:consolidationDegree>
  - <gsml:CGI_TermValue>
    <gsml:value codeSpace="urn:cgi:classiferScheme:BGS:consolidationTerms">INDURATED</gsml:value>
  </gsml:CGI_TermValue>
</gsml:consolidationDegree>
<gsml:lithology xlink:href="urn:cgi:classifer:BGS:RCS:MECA" />
</gsml:RockMaterial>

```

Figure 24: Example of lithology encoding with ConstituentParts

Points to note from Figure 24:

- The RockMaterial is made up of two ConstituentParts which are also RockMaterials
- This example is taken from a RockMaterial vocabulary and the lithology of each of the two component RockMaterials is referenced to a ControlledConcept defined elsewhere in the vocabulary
- The role property describes the role of the ConstituentPart in the overall RockMaterial.
- The proportion property indicates the proportion the ConstituentPart forms of the overall RockMaterial. It can be given either as a term value, as in this example, or as a numeric value (such as a percentage).
- The ConstituentPart of a RockMaterial is similar to the CompositionPart of a GeologicUnit. The lithology of a CompositionPart might be a RockMaterial which was made up of ConstituentParts
- The lithology, geneticCategory and optional consolidationDegree properties are given for both the primary RockMaterial and the two ConstituentPart RockMaterials

4.6 The delivery of mapped structural features

4.6.1 Contacts

The contacts between GeologicUnits are modelled as a type of GeologicStructure (see section 3.2.4), and would commonly be delivered as MappedFeatures. Figure 25 is an example of a MappedFeature specified by a Contact.

```
- <gsml:MappedFeature gml:id="GA_Mapped_Contact_24680">
- <gsml:observationMethod>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="urn:cgi:classiferScheme:GA:1MillionGeology_ObservationMethods">Geological Survey of New South Wales, Statewide geodatabases
  1:250,000 scale or better, 2003. Simplified, edge matched and modified for representation at 1:1 million scale</gsml:value>
</gsml:CGI_TermValue>
</gsml:observationMethod>
- <gsml:positionalAccuracy>
- <gsml:CGI_NumericValue>
  <gsml:principalValue uom="urn:ogc:def:uom:UCUM:m">500</gsml:principalValue>
</gsml:CGI_NumericValue>
</gsml:positionalAccuracy>
<gsml:samplingFrame xlink:href="urn:cgi:feature:CGI:EarthNaturalSurface" />
- <gsml:specification>
- <gsml:Contact gml:id="GA_Contact_24680">
  <gml:description>Geological boundary</gml:description>
- <gsml:observationMethod>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="urn:cgi:classiferScheme:GA:ObservationMethods">published map</gsml:value>
</gsml:CGI_TermValue>
</gsml:observationMethod>
<gsml:purpose>Instance</gsml:purpose>
- <gsml:contactType>
- <gsml:ControlledConcept gml:id="GA_FeatureCode_1000100">
  <gml:description>Geological boundary</gml:description>
  <gml:name codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:feature:GA:FeatureCode:Feat_code:1000100</gml:name>
  <gsml:name xml:lang="en" codeSpace="urn:cgi:classiferScheme:GA:FeatureCode:Description">Geological boundary</gsml:name>
  <gsml:vocabulary xlink:href="urn:cgi:classiferScheme:GA:FeatureCode" />
  </gsml:ControlledConcept>
</gsml:contactType>
- <!--
  <gsml:boundedUnitLink> *** Example of the potential use of boundedUnitLink ****
    <gsml:BoundaryRelationship>
      <gml:description>Conformable stratigraphic boundary</gml:description>
      <gsml:relationship codeSpace="urn:cgi:classiferScheme:GA:Relations">Stratigraphic boundary - conformity</gsml:relati
      <gsml:sourceRole codeSpace="urn:cgi:classiferScheme:GA:Role">overlying unit</gsml:sourceRole>
      <gsml:targetRole codeSpace="urn:cgi:classiferScheme:GA:Role">underlying unit</gsml:targetRole>
      <gsml:target xlink:href="GA_Stratigraphic_Lexicon.xml#GA_Stratno_33373"/>
      <gsml:source xlink:href="GA_Stratigraphic_Lexicon.xml#GA_Stratno_24881"/>
      </gsml:BoundaryRelationship>
    </gsml:boundedUnitLink>
  -->
</gsml:Contact>
</gsml:specification>
```

Figure 25: Example of encoding of a Contact as a MappedFeature

Points to note from Figure 25:

- The pattern of a MappedFeature specification by GeologicStructures, like Contact, is identical to the specification by a GeologicUnit
- The optional contactType property in this example uses a user provided vocabulary. There is also a CGI ContactType vocabulary available to aid interoperability
- In Figure 20 there is an example of the use of GeologicRelation to describe the relationship between GeologicUnits. BoundaryRelationship is a particular type of GeologicRelation for describing the relationship between a Contact and its bounding GeologicUnits. In Figure 25 there is a 'commented' example of the use of BoundaryRelationship.

4.6.2 Faults and Ductile shear structures

Faults and DuctileShearStructures are both types of ShearDisplacementStructure (see section 3.2.4) and follow identical encoding patterns.

A DuctileShearStructure is a parallel-sided zone of localised shearing displacement which may contain sigmoidal mineral-filled veins, locally well-developed cleavage or foliation, wholesale grain size reduction or mylonitisation, or a combination of these features. It generally occurs in a discrete tabular zone (very thin compared to its along-strike and down dip dimensions) of plastic deformation across which there has been shear displacement. A DuctileShearStructure is a map-scale feature.

Figure 26 is an example of a MappedFeature specified by a DuctileShearStructure. It follows the same pattern as used for Contacts (see section 4.6.1).

```

- <gsm:MappedFeature gml:id="GA_Mapped_Structure_123457">
- <gsm:observationMethod>
- <gsm:CGI_TermValue>
  <gsm:value codeSpace="urn:cgi:classiferScheme:GA:1MillionGeology_ObservationMethods">Blake, D.H., 1987, Mt Isa Inlier and Environs 1:500,000,
  Bureau of Mineral Resources</gsm:value>
  </gsm:CGI_TermValue>
  </gsm:observationMethod>
- <gsm:positionalAccuracy>
- <gsm:CGI_NumericValue>
  <gsm:principalValue uom="urn:ogc:def:uom:UCUM:m">1000</gsm:principalValue>
  </gsm:CGI_NumericValue>
  </gsm:positionalAccuracy>
- <gsm:samplingFrame xlink:href="urn:ogc:feature:CGI:EarthNaturalSurface" />
- <gsm:specification>
- <gsm:DuctileShearStructure gml:id="GA_Shear_123457">
  <gml:description>Shear zone, concealed</gml:description>
  <gml:name>WELLINGTON SHEAR ZONE</gml:name>
  <gsm:observationMethod>
  - <gsm:CGI_TermValue>
    <gsm:value codeSpace="urn:cgi:classiferScheme:GA:ObservationMethods">published map</gsm:value>
    </gsm:CGI_TermValue>
    </gsm:observationMethod>
    <gsm:purpose>instance</gsm:purpose>
  </gsm:DuctileShearStructure>
  </gsm:specification>
- <gsm:shape>
- <gml:LineString srsName="urn:ogc:def:crs:EPSG:4326">
  <gml:posList>144.489331964981 -38.3184902482694 144.489931237995 -38.3183664057308 144.490906986438 -38.3181475108326
  144.49188273488 -38.3179286159343 144.492858483323 -38.3177097210361 144.493834231766 -38.3174908261378 144.494809980209 -
  38.3172719312396 144.495785728651 -38.3170530363413 144.496761477094 -38.316834141443 144.497737225537 -38.3166152465448
  144.49871297398 -38.3163963516465 144.499688722422 -38.3161774567483 144.499917071007 -38.3161262300817 144.500900074584 -
  38.315942643681 144.501320188152 -38.3158641829922 144.50231126013 -38.3157308550757 144.503302332109 -38.3155975271592
  144.504293404087 -38.3154641992428 144.505284476066 -38.3153308713263 144.506275548045 -38.3151975434098 144.507266620023 -
  38.3150642154933 144.508257692002 -38.3149308875768 144.50924876398 -38.3147975596603 144.510239835959 -38.3146642317438
  144.511230907937 -38.3145309038274 144.512221979916 -38.3143975759109 144.513213051894 -38.3142642479944 144.514204123873 -
  38.3141309200779 144.515195195852 -38.3139975921614 144.51618626783 -38.3138642642449 145.516207765925 -
  38.3138613721278</gml:posList>
  </gml:LineString>
  </gsm:shape>
</gsm:MappedFeature>

```

Figure 26: Example of encoding of a DuctileShearStructure as a MappedFeature

A Fault is defined as a discrete surface, or zone of discrete surfaces, with some thickness, separating two rock masses across which one mass has slid past the other and characterized by brittle deformation. A Fault is a map-scale feature. When observed in outcrop, some Faults are just

big breccia/gouge zones with no discrete surfaces, sometimes they are breccia/gouge zones bounded by discrete fault surfaces, and sometimes they are a discrete surface in relatively unbroken rock (at the scale of description).

Figure 27 is an example of a MappedFeature specified by a Fault.

```

- <gsm:MappedFeature gml:id="BRGM_Mapped_Structure_12345">
  <gml:name>L_STRUCT_12345</gml:name>
  - <gsm:observationMethod>
    - <gsm:CGI_TermValue>
      <gsm:value codeSpace="http://www.cgi-iugs.org/uri">urn:cg:classifier:CGI:MappedFeatureObservationMethod:published_map</gsm:value>
    </gsm:CGI_TermValue>
  </gsm:observationMethod>
  - <gsm:positionalAccuracy>
    - <gsm:CGI_NumericValue>
      <gsm:principalValue uom="urn:ogc:def:uom:UCUM:m">500</gsm:principalValue>
    </gsm:CGI_NumericValue>
  </gsm:positionalAccuracy>
  <gsm:samplingFrame xlink:href="urn:cg:feature:BRGM:France" />
  - <gsm:specification>
    - <gsm:Fault gml:id="BRGM_Structure_12345">
      <gml:name>Faille de Mazamet</gml:name>
      - <gsm:observationMethod>
        - <gsm:CGI_TermValue>
          <gsm:value codeSpace="http://urn.opengis.net">urn:ogc:def:nil:OGC:missing</gsm:value>
        </gsm:CGI_TermValue>
      </gsm:observationMethod>
      <gsm:purpose>instance</gsm:purpose>
      - <gsm:planeOrientation>
        - <gsm:CGI_PlanarOrientation>
          <gsm:convention>dip dip direction</gsm:convention>
          <gsm:polarity>not applicable</gsm:polarity>
        </gsm:CGI_PlanarOrientation>
      </gsm:planeOrientation>
    </gsm:Fault>
  </gsm:specification>
  - <gsm:shape>
    - <gml:LineString srsName="urn:ogc:def:crs:EPSG:6.15:4326">
      <gml:posList>1.59 50.70 1.90 50.87</gml:posList>
    </gml:LineString>
  </gsm:shape>
</gsm:MappedFeature>

```

Figure 27: Example of encoding of a Fault as a MappedFeature

Points to note in Figure 27:

- planeOrientation is encoded using the CGI_PlanarOrientation data type which has mandatory properties of convention and polarity, and optional properties of azimuth and dip
- The values of convention and polarity should be taken from the enumeration lists ConventionCode and PlanarPolarityCode respectively

4.7 The delivery of borehole data

As described in section 3.2.7 there are two ways in which boreholes can be encoded, depending on the nature of the information available for the borehole and the purpose for which it is being delivered. A Borehole is a type of SamplingCurve, SamplingCurve being defined in the OGC Observations & Measurements (O&M) package. This enables observations in a borehole log to be encoded as relatedObservations, in the same way as for any other O&M SamplingFeature. In addition, however, the logElement association to MappedInterval can be used to encode Borehole logs as MappedFeatures. Whichever approach is used the collarLocation association can provide information on the Borehole location and the indexData association can provide index information which is specific to Boreholes.

Figure 28 shows the encoding of Borehole geometry, which is common to either the O&M or MappedInterval approaches.

```

- <gsml:Borehole xmlns="urn:cgi:xmlns:CGI:GeoSciML:2.0" gml:id="bh.TR34SWBJ90" xmlns:om="http://www.opengis.net/om/1.0"
  xmlns:sa="http://www.opengis.net/sampling/1.0" xmlns:cv="http://www.opengis.net/cv/0.2.1">
  <gml:name codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:feature:BGS:SOBI:TR34SW/BJ/90/.</gml:name>
  <gml:name>ELMS VALE</gml:name>
  <sa:sampledFeature xlink:role="urn:cgi:featureType:CGI:GeoSciML:2.0:GeologicUnit" xlink:href="urn:ogc:def:nil:OGC:unknown">
- <sa:shape>
- <gml:LineString gml:id="bh.TR34SWBJ90.shape" srsName="urn:ogc:def:crs:EPSG:6.15:7405" srsDimension="3">
  <gml:pos>630400 0141150 29.5</gml:pos>
  <gml:pos>630400 0141150 74.5</gml:pos>
  </gml:LineString>
</sa:shape>
<sa:length uom="urn:ogc:def:uom:UCUM:m">45.0</sa:length>
- <gsml:collarLocation>
- <gsml:BoreholeCollar>
- <gsml:location>
  - <gml:Point srsName="urn:ogc:def:crs:EPSG:6.15:27700" srsDimension="2">
    <gml:pos>630400 0141150</gml:pos>
    </gml:Point>
  </gsml:location>
  <gsml:elevation srsName="urn:ogc:def:crs:EPSG:6.15:5701" srsDimension="1">29.5</gsml:elevation>
</gsml:BoreholeCollar>
</gsml:collarLocation>

```

Figure 28: Example of encoding borehole geometry information

Points to note from Figure 28:

- In this example sampledFeature is used to indicate the type of feature sampled (in this case GeologicUnit). The instances of GeologicUnit sampled will be indicated by the specification of individual MappedIntervals. Where a borehole is being encoded as relatedObservations rather than MappedIntervals then multiple values for sampledFeature can be used to reference each GeologicUnit (for example in a StratigraphicLexicon) on which relatedObservations have been made (see Figure 30)
- The shape of a borehole should be a LineString in 3D space, defined using a 3D coordinate system. The coordinate reference system should, ideally, be one defined in the EPSG registry at <http://www.epsg-registry.org/>
- The collarLocation for the Borehole is defined using a 2D location value and a 1D elevation value. Both values should be defined using the appropriate 2D and 1D coordinate reference system. The coordinate reference systems should, ideally, be ones defined in the EPSG registry at <http://www.epsg-registry.org/>

4.7.1 The MappedInterval method

A MappedInterval is a type of MappedFeature and the encoding of Boreholes as MappedIntervals is very similar to the encoding of GeologicUnits as MappedFeatures.

Figure 29 is an example of the encoding of a Borehole as a MappedInterval.

```

- <gsml:logElement>
- <gsml:MappedInterval>
- <gsml:observationMethod>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:classifier:CGI:FeatureObservationMethod:2008:drill_core_observation</gsml:value>
</gsml:CGI_TermValue>
</gsml:observationMethod>
- <gsml:positionalAccuracy>
- <gsml:CGI_NumericValue>
  <gsml:principalValue uom="urn:ogc:def:uom:UCUM:m">0.1</gsml:principalValue>
</gsml:CGI_NumericValue>
</gsml:positionalAccuracy>
<gsml:samplingFrame xlink:href="#bh.TR34SWBJ90" />
- <gsml:specification>
- <gsml:GeologicUnit>
  <gml:name codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:classifier:BGS:StratigraphicLexicon:MADE_GROUND</gml:name>
- <gsml:observationMethod>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:classifier:CGI:FeatureObservationMethod:2008:drill_core_observation</gsml:value>
</gsml:CGI_TermValue>
</gsml:observationMethod>
<gsml:purpose>instance</gsml:purpose>
<gsml:geologicUnitType xlink:href="urn:cgi:classifier:CGI:GeologicUnitClassification:2008:ArtificialGround" />
<gsml:classifier xlink:href="urn:cgi:classifier:BGS:StratigraphicLexicon:MADE_GROUND" />
- <gsml:composition>
- <gsml:CompositionPart>
  <gsml:role codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:classifier:CGI:GeologicUnitPartRole:2008:only_part</gsml:role>
<gsml:lithology xlink:href="urn:cgi:classifier:CGI:SimpleLithology:2008:anthropogenic_material" />
- <gsml:proportion>
- <gsml:CGI_TermValue>
  <gsml:value codeSpace="http://www.cgi-iugs.org/uri">urn:cgi:classifier:CGI:ProportionTerm:2008:all</gsml:value>
</gsml:CGI_TermValue>
</gsml:proportion>
</gsml:CompositionPart>
</gsml:composition>
</gsml:GeologicUnit>
</gsml:specification>
- <gsml:shape>
- <gml:LineString srsName="bh.TR34SWBJ90.shape" srsDimension="1">
  <gml:pos>0</gml:pos>
  <gml:pos>1.0</gml:pos>
</gml:LineString>
</gsml:shape>
</gsml:MappedInterval>
</gsml:logElement>

```

Figure 29: Example encoding a borehole log as MappedIntervals

Points to note from Figure 29:

- The logElement association from Borehole allows the borehole log to be recorded as a sequence of MappedIntervals. This example shows the first logElement of the borehole log
- MappedInterval is a type of MappedFeature and is encoded in the same way
- For a MappedInterval positionalAccuracy refers to the measurement of depth in the borehole
- The samplingFrame is the borehole itself, defined by its identifier which is the gml:id of the borehole (see Figure 28)
- Each MappedInterval must be specified by a GeologicFeature, in this case a GeologicUnit. The GeologicUnit is encoded in exactly the same way as for geologic maps (see section 4.4.1)
- The shape of the MappedInterval is defined as a depth interval along the borehole, in this case from 0 – 1.0. This is measured in terms of a 1D spatial reference system for the borehole, identified by the gml:id of the LineString defining the borehole (see Figure 28)

4.7.2 The Observations & Measurements method

Using the Observations & Measurements method each type of observation, such as lithology or age, is a distinct relatedObservation. Each relatedObservation has a result with an element for each value for that type of observation, for example for each lithology observation made down a borehole. Figure 30 is an example of coding a lithology log as relatedObservations with the first two elements down the borehole shown.

```

<sa:sampledFeature xlink:href="urn:cgi:classifer:BRGM:StratigraphicLexicon:50K:F001" />
<sa:sampledFeature xlink:href="urn:cgi:classifer:BRGM:StratigraphicLexicon:50K:F010" />
<sa:sampledFeature xlink:href="urn:cgi:classifer:BRGM:StratigraphicLexicon:50K:F145" />
<!-- Lithologies encoded according to the O&M schema -->
- <sa:relatedObservation>
- <om:Observation gml:id="bh.30303239375830303131.lithology.1">
  <om:samplingTime xlink:href="urn:ogc:def:nil:OGC:unknown" />
  <om:procedure xlink:href="urn:cgi:classifer:CGI:FeatureObservationMethod:drill_core_observation_estimated_values" />
  <om:observedProperty xlink:href="urn:cgi:propertyType:CGI:GeoSciML:2.0:CompositionPart:lithology" />
  <om:featureOfInterest xlink:role="urn:cgi:featureType:CGI:GeoSciML:2.0:GeologicUnit" xlink:href="urn:ogc:def:nil:OGC:unknown" />
- <om:result>
- <cv:CV_DiscreteCoverage>
  <cv:domainExtent xlink:href="#bh.30303239375830303131.Shape" />
  <cv:rangeType xlink:href="urn:ogc:def:nil:OGC:unknown" />
  - <cv:element>
  - <cv:CV_GeometryValuePair>
    - <cv:geometry>
      - <cv:CV_DomainObject>
        - <cv:spatialElement>
          <!-- An identifier is defined for the geometry of the interval in order to refer to this geometry in another set of observations. The aim is to
          not duplicate -->
          - <gml:LineString srsName="#bh.30303239375830303131.Shape" srsDimension="1" gml:id="bh.30303239375830303131.1">
            <gml:pos>0</gml:pos>
            <gml:pos>0.4</gml:pos>
          </gml:LineString>
        </cv:spatialElement>
      </cv:CV_DomainObject>
    </cv:geometry>
    <!-- Lithology value according to the CGI simple lithology dictionary -->
    <cv:value xsi:type="gml:ReferenceType" xlink:href="urn:cgi:classifer:CGI:SimpleLithology:2008:anthropogenic_unconsolidated_material" />
  </cv:CV_GeometryValuePair>
  - <cv:element>
  - <cv:CV_GeometryValuePair>
    - <cv:geometry>
      - <cv:CV_DomainObject>
        - <cv:spatialElement>
          <!-- An identifier is defined for the geometry of the interval in order to refer to this geometry in another set of observations. The aim is to
          not duplicate -->
          - <gml:LineString srsName="#bh.30303239375830303131.Shape" srsDimension="1" gml:id="bh.30303239375830303131.2">
            <gml:pos>0.4</gml:pos>
            <gml:pos>2</gml:pos>
          </gml:LineString>
        </cv:spatialElement>
      </cv:CV_DomainObject>
    </cv:geometry>
    <!-- Lithology value according to the CGI simple lithology dictionary -->
    <cv:value xsi:type="gml:ReferenceType" xlink:href="urn:cgi:classifer:CGI:SimpleLithology:2008:sedimentary_rock" />
  </cv:CV_GeometryValuePair>
  </cv:element>

```

Figure 30: Example of encoding a lithology borehole log using the O&M method

Points to note from Figure 30:

- Multiple values of sampledFeature are used to reference each GeologicUnit (for example in a StratigraphicLexicon) on which relatedObservations have been made
- samplingTime, procedure, observedProperty, and featureOfInterest are all mandatory properties for an Observation. Where the value of any of these is unavailable then a reference to an OGC nil value, such as "urn:ogc:def:nil:OGC:unknown", should be given
- observedProperty indicates the property being measured, in this case lithology
- featureOfInterest indicates the type of feature being observed, in this case GeologicUnit. Note that this is distinct from the specific GeologicUnits encountered by the borehole which are recorded by sampledFeature
- An observation result can be of any type. In the case of a borehole it is a DiscreteCoverage, the elements of which are intervals down the borehole
- The domainExtent of the result defines the extent of the spatiotemporal domain of the coverage. For boreholes this is the borehole itself, identified by the gml:id of the LineString defining the borehole
- Each element of the result contains the geometry of the interval being measured along with the value of the measurement. In the case of a borehole the geometry is defined as a depth interval along the borehole measured in terms of a 1D spatial reference system for the borehole, identified by the gml:id of the LineString defining the borehole. This is the same way that MappedIntervals are defined (see Figure 29)
- In this example the lithology measurement value is recorded by reference to a value in the CGI SimpleLithology vocabulary (eg sedimentary_rock)

4.8 The delivery of outcrop data

The Observations and Measurements package is also used to encode field observations made at outcrop. The SamplingFeatureCollection (see Figure 31) is the class to use for representing geoscience field data, e.g. geologic unit descriptions, fault description, contact description, structural measurements, or specimens. An outcrop is modelled as a SamplingFeatureCollection of SamplingPoints (a type of SamplingFeature) at which observations are made. Best practice is to describe observations on one GeologicFeature at each SamplingPoint and to relate these observations (eg unit descriptions and structural measurements) using SamplingFeatureRelation. The SamplingFeatureCollection will contain the SamplingPoints, with the various types of relatedObservation, along with the relatedSamplingFeatures, the sampledFeatures and surveyDetails

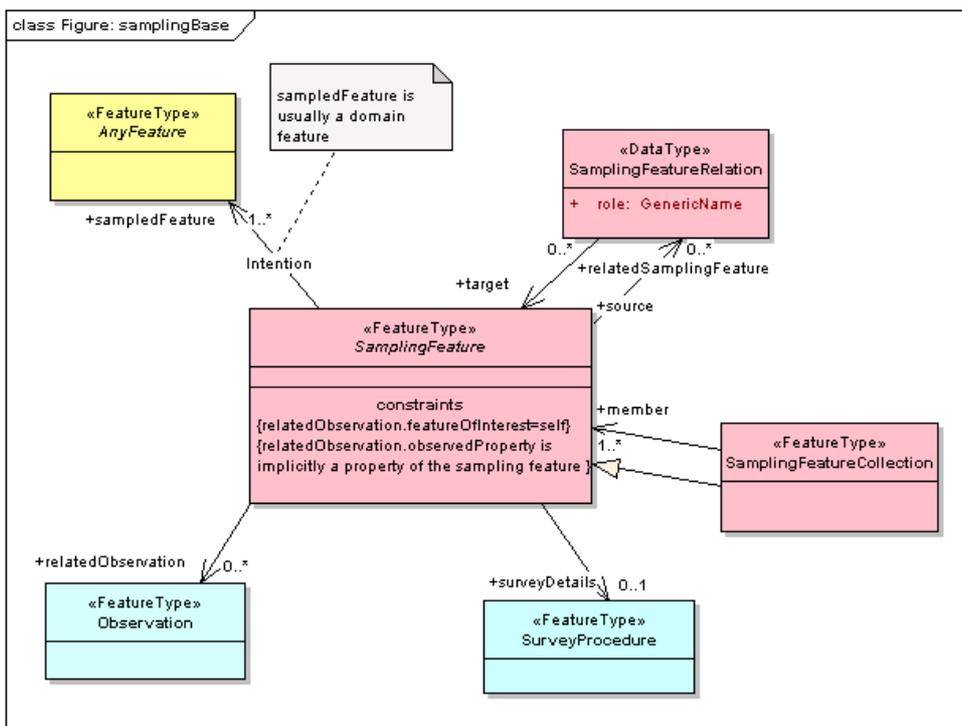


Figure 31: UML Diagram for the samplingBase component of the Observations & Measurements package

Figure 32 gives an example of encoding outcrop observations as a collection of SamplingPoints in a SamplingFeatureCollection.

```

- <sa:SamplingFeatureCollection gml:id="FieldSite_93846001">
- <!--
=====
NOTE that a SamplingFeatureCollection does not have a location (geometry) of its own. Its geometry is inferred of the locations of its members
In this example, all the SamplingPoints that make up the outcrop have the same point location.
=====
-->
-->
<gml:description> Molong-Manildra Road </gml:description>
<gml:name> FieldSite 93846001 </gml:name>
<sa:sampledFeature xlink:href="#GA_GeolUnit_9925_1502034" />
<!-- See GeologicUnit descriptions in SamplingPoints below -->
<sa:sampledFeature xlink:href="#GA_GeolUnit_134_123456" />
<sa:sampledFeature xlink:href="#GA_Structure_45134" />
<!-- See Foliation description in SamplingPoints below -->
<!-- A first GeologicUnit observation point at the outcrop. -->
<!--
-->
- <sa:member>
- <sa:SamplingPoint gml:id="FieldSite_93846001_01">
- <sa:sampledFeature>
- <gml:GeologicUnit gml:id="GA_GeolUnit_9925_1502034">

```

..... in this example the sampledFeature is a GeologicUnit description which can be given in-line or by reference.....

```

</gsm:GeologicUnit>
</sa:sampledFeature>
- <sa:relatedObservation>
- <om:Observation>
- <om:samplingTime>
- <gml:TimeInstant gml:id="GA_SamplingDate_FieldSite_93846001">
  <!-- Reuse this time ID for samplingTime of all samples and observations at this outcrop -->
  <gml:timePosition>1993-04-27</gml:timePosition>
</gml:TimeInstant>
</om:samplingTime>
<om:procedure xlink:href="urn:cgi:classifier:GA:ObservationMethods:FieldMapping" />
<om:observedProperty xlink:href="urn:cgi:featureType:CGI:GeoSciML:2.0:CompositionPart:material" />
<om:featureOfInterest xlink:href="#FieldSite_93846001_01" />
<!-- F.O.I. xlink to the SamplingPoint. Redundant information in this particular use of Observation, but is required by G&M for other situations where
Observation is not accessed via a samplingFeature -->
- <om:result>
- <gsm:material>
- <gsm:RockMaterial gml:id="GA_Rock_1502034">

```

....in this example the result is a RockMaterial description, which can be given in-line or by reference....

```

</gsm:RockMaterial>
</gsm:material>
</om:result>
</om:Observation>
</sa:relatedObservation>

```

Figure 32: Example of encoding a lithology observation at an outcrop

Points to note from Figure 32:

- Multiple values of sampledFeature are used to reference each GeologicUnit on which relatedObservations have been made for the SamplingFeatureCollection (see Figure 30 for equivalent use for Borehole observations).
- Each member of the SamplingFeatureCollection identifies the sampledFeature. In this example the sampledFeature (a GeologicUnit) was encoded in-line at this point but this has been omitted from Figure 32 for clarity. The sampledFeature could reference a feature in, for example, a StratigraphicLexicon
- relatedObservations are encoded in the same way as for Boreholes (see Figure 30), but in this example the result of the observation is a RockMaterial description. It could be any other type of observation made at an outcrop

Figure 33 gives an example of the encoding of the, optional, surveyDetails. This example gives positionMethod, the only mandatory property, and positionAccuracy. In addition surveyDetails allows the recording of elevationAccuracy, elevationDatum, elevationMethod, geodeticDatum, operator, projection and surveyTime if required.

```

- <sa:surveyDetails>
- <sa:SurveyProcedure gml:id="FieldSite_93846001_survey">
  <!-- First inline, then by reference for all members of this SamplingFeatureCollection -->
  - <sa:positionMethod>
  - <omx:ObservationProcess>
    <omx:method codeSpace="urn:cgi:classifierScheme:GA:LocationMethod">GPS observation (WGS84 - World Geodetic System 1984)</omx:method>
  </omx:ObservationProcess>
  </sa:positionMethod>
  <sa:positionAccuracy uom="urn:ogc:def:uom:UCUM:m">50</sa:positionAccuracy>
</sa:SurveyProcedure>
</sa:surveyDetails>

```

Figure 33: Example of encoding of surveyDetails

Figure 34 gives an example of the encoding of a relatedSamplingFeature.

```

- <sa:relatedSamplingFeature>
- <sa:SamplingFeatureRelation>
  <sa:role>Specimen sampled from geologic unit</sa:role>
- <sa:target>
- <sa:LocatedSpecimen gml:id="GA_Specimen_93846001a">
  <gml:description>hand specimen</gml:description>
  <gml:name>93846001a</gml:name>
  <sa:sampledFeature xlink:href="#GA_GeolUnit_134_123456" />
  <sa:materialClass codeSpace="urn:cgi:classifierScheme:GA:SampleMaterial">rock</sa:materialClass>
  <sa:samplingTime xlink:href="#GA_SamplingDate_FieldSite_93846001" />
  <!-- xlink to Outcrop/SamplingTime. See above. -->
  <sa:samplingLocation xlink:href="#GA_FieldSiteLocation_93846001" />
  <!-- xlink to Outcrop/position, see below. -->
</sa:LocatedSpecimen>
</sa:target>
</sa:SamplingFeatureRelation>
</sa:relatedSamplingFeature>

```

Figure 34: Example of encoding of a relatedSamplingFeature

Points to note from Figure 34:

- Each relatedSamplingFeature must have a role describing its relation to the target SamplingFeature
- The target can be any type of SamplingFeature. In this example it is a LocatedSpecimen, that is a Specimen (see Figure 8) with a samplingLocation
- LocatedSpecimens have mandatory properties of materialClass, samplingTime and samplingLocation. They also have optional properties of currentLocation, samplingMethod and size