Background Information for CAAML V5.0 Profile

Snow Profile IACS

Purpose of Document

The purpose of this document is provide important background information on the CAAML V5.0 profile 'Snow Profile IACS' to facilitate the adoption of the standard. This document is not intended to discuss every detail of CAAML and the profile and involved developers and programmers are expected to have a working understanding of avalanche safety and snow science information. This document will continuously be updated as more questions arise from the user community.

For any questions regarding CAAML or this particular profile, please contact Pascal Haegeli at pascal@avisualanche.ca.

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1.1 Purpose of CAAML

CAAML is an XML (eXtensible Markup Language) grammar that can be used to encode avalanche and snow science related information and exchange it over the internet. CAAML defines the structure and elements of observation types, specifies how locations are referenced, provides a mechanism for linking observations with each other and contains a method for associating external data files.

1.2 Scope of CAAML

CAAML aims to provide a common encoding structure for all types of information exchanged by avalanche safety practitioners, scientists, and other potential users. Types of observations that are currently supported by CAAML include:

- Avalanche accident information
- Avalanche activity comments (general)
- Avalanche observations (detailed)
- Avalanche bulletins
- Avalanche closures
- Field observations
- Snowpack structure comments
- Snow profile observations
- Stability assessments
- Weather observations (detailed)
- Weather synopsis comment (general)

1.3 Versions of CAAML

The initial version of CAAML was published in 2003. Since then, five different versions of CAAML have been published.

- **CAAML V1.0.3 (deprecated)**
  The initial specifications for CAAML were developed to support an electronic submissions of the industrial information exchange (InfoEx©) of the Canadian Avalanche Association. These specifications were limited to support observation elements that had traditionally been exchanged in the InfoEx©.
- **CAAML V2.2.6 (deprecated)**
  For this version, CAAML was expanded to include the majority of specification defined in the Observation Guidelines and Recording Standards (OGRS) of the Canadian Avalanche Association.
- **CAAML V3.0.3 (deprecated)**
  In order to support more detailed geographic information in CAAML, the standard was modified to incorporate key elements of GML, the XML standard for geographic information.

- **CAAML V4.2 (operational - new adoptions not recommended)**
  The file structure of CAAML schema files was redesigned to allow CAAML to be used as an international standard that is not necessarily tied to Canadian element definitions. At the same time, the schema was made fully GML compliant and additional modules for avalanche accident information and snow profile observations were added.
- **CAAML V5.0 (in development)**
  This is the first version of CAAML that uses the concept of Profiles to facilitate the adoption of the standard for specific applications. Furthermore, the schema file structure was redesigned to more properly derive observation and element types.

1.4 Structure of CAAML

In this section we will briefly discuss the main structural characteristics of the CAAML standard.

1.4.1 Incorporated XML standards

CAAML builds on two existing XML standards

- **GML (Geographic Markup Language)**
  GML is the XML grammar defined by the Open Geospatial Consortium (OGC) to express geographic features. CAAML uses existing GML type definitions for encoding the spatial information of locations.
- **XLink (XML Linking Language)**
  XLink is an XML markup language and World Wide Web Consortium (W3C) specification that provides methods for creating internal and external links within XML documents. CAAML uses XLink attributes for defining links between objects.

1.4.2 Schema files

The latest version of CAAML, Version 5.0, consists of nine individual schema files.

- **xlinks.xsd**
  This file provides the definitions for the attributes that are used to refer to other elements in CAAML and GML objects.
- **gml.3.2Profile.xsd**
  This file contains all GML type and element definitions used in CAAML 5.0. It is a logical restriction of the complete GML 3.2 definition.
- **caaml_ValuesScalar.xsd**
  This file contains all the type and element definitions of scalar property and value elements used in CAAML objects and observations.
- **caaml_ValuesList.xsd**
  This file contains all the type and element definitions of array and tuple list values used in CAAML observations.

- **caaml_ValuesComposite.xsd**
  This file contains the type and element definitions of composite property and values elements used in CAAML objects and observations.
- **caaml_ObjectsBase.xsd**
  This file contains the base definitions of all objects used in CAAML and the heads of their substitution groups. Most of the elements are abstract, meaning that it is not possible to directly use them in a CAAML file.
- **caaml_ObjectsGeometry.xsd**
  This file contains a limited number of definitions for base geometry property element of CAAML location and observation elements.
- **caaml_ObjectsAndObservations.xsd**
  This file contains all of the object and observation definitions for CAAML. Since there are many cross-references between objects, it is impossible to further separate the definitions included in this file.
- **caaml.xsd**
  This is the top CAAML schema file, which contains the definition of the <caamlData> wrapper element.

The relationship of the various files is illustrated in Figure 1.

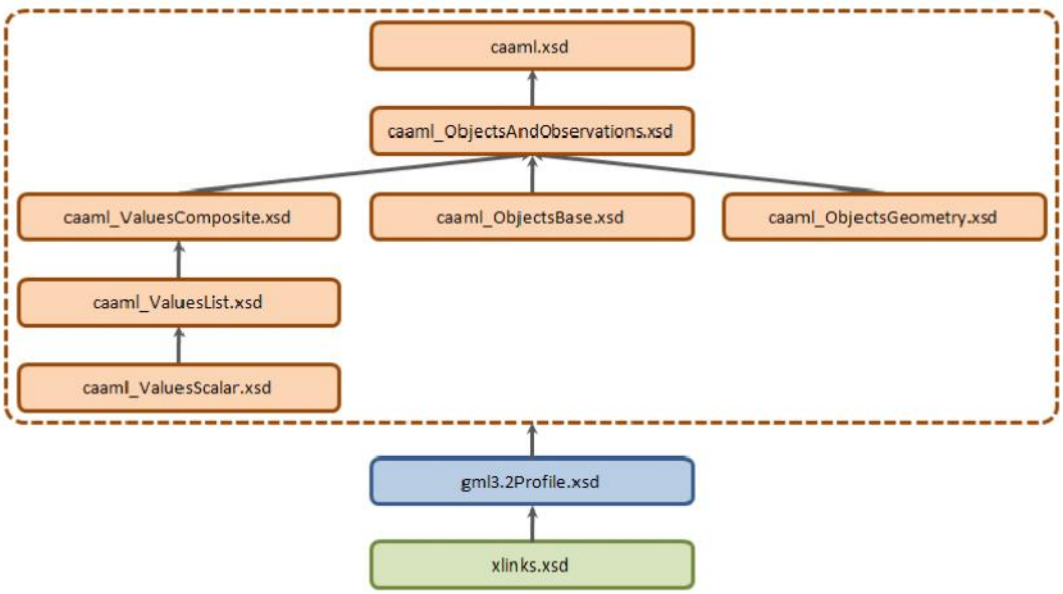

Figure 1: File structure of CAAML V5.0

1.5 Encoding conventions

1.5.1 Object-Property Model

Following the lead of GML, the arrangement of elements in CAAML reflects the object-property model pattern, which is partially based on the class-property model of the Resource Description Framework (RDF; http://www.w3.org/TR/rdf-schema/). The object-property model is encoded in CAMML by declaring a type and then assigning properties to that type. The following CAAML snippet illustrates the pattern by showing how the information of an operation is encoded.

```
<Operation>
	<name>Heliski Company</name>
	<town>Deep Powder Town</town>
	<employees>
		<Person>
			<name>John Doe</name>
		</Person>
	</employees>
</Operation>
```

Notice that objects are labelled in UpperCamelCase, while property elements are labelled in lowerCamelCase. This convention is used throughout GML and CAAML to distinguish between property and type elements.

1.5.2 Attributes

Similar as in GML, the use of attributes are kept to a minimum in CAAML. With a few exceptions, attributes are only used for

- Identifiers (`gml:id`)
- Units
- XLink attributes

1.5.3 Focus on raw data

CAAML aims to facilitate the exchange of raw data. The exchange of elaborated data or computed interpretations is beyond the scope of the standard. It is encouraged that data interpretations are calculated by the end-user based on published methods, particularly if corresponding codes are available.

If a specific user group needs to exchange data that is currently not included in the CAAML standard, they are encouraged to define the necessary XML elements and include them in the CAAML file under the appropriate `<customData>` element. See section 4.1 for more details. As these data element become more established, they can formally be adopted into the standard during the next scheduled revision of the standard.

2 CAAML profiles

Since the data characteristics and requirements vary dramatically among different avalanche safety programs and related research projects, CAAML was designed as a comprehensive and highly flexible standard. To allow the adoption of CAAML by a broad audience, it is impractical to tightly define the data structure in CAAML and force all applications to encode information in the exact same way. However, at the same time, there are many similarities among the data collected and encoding this information in a similar fashion is highly desirable.

Due to its comprehensiveness and flexibility, working for CAAML can be overwhelming and frustrating. For a specific application, developers often only need a small subset of the elements defined in CAAML. To simplify the adoption of CAAML by programmers while maintaining its flexibility, CAAML V5.0 introduced CAAML profiles, another concept borrowed from GML. Profiles are logical restrictions of CAAML that focus on the observation elements relevant for the specific application while maintaining the common structural elements.

The division of tasks between CAAML and CAAML profiles are as follows:

CAAML	CAAML Profile
• Complete definition of structure	• Tight restriction to application relevant elements • Definition of enumerations

With this approach, all CAAML files that validate against a specific CAAML Profile automatically also validate against the same generation overall CAAML standard.

Note that profiles are distinctly different from application schemas. While CAAML profiles are part of the CAAML namespace and every XML file that validates against a CAAML profile also validates against the overall CAAML standard, related application schemas are XML vocabularies that use CAAML but reside in a application-specific namespace and are therefore not compatible.

3 CAAML profile Snow Profile IACS

3.1 Purpose of Snow Profile IACS

The 'Snow Profile IACS' is derived from CAAML V5.0 and aims to facilitate the exchange of snow profile information. This standard only contains the subset of CAAML elements needed for exchanging snow profile information. The standard defines the core observation elements for snow profiles including their enumerations and value ranges following the International Classification for Seasonal Snow on the Ground (Fierz *et al.*, 2009) published jointly by UNESCO and the International Association for Cryospheric Sciences (IACS).

3.2 Schema files

This CAAML profile consists of two separate schema files:

- **CAAMLv5_SnowProfileIACS.xsd**
  This file contains the restricted CAAML V5.0 definitions for snow profile information according to the IACS standard.
- **CAAMLv5_SnowProfileIACS_GML.xsd**
  This file is a profile itself, which contains the GML 3.2 definitions required in Snow Profile IACS.

The schema files are available at http://caaml.org/Schemas/V5.0/Profiles/SnowProfileIACS.

3.3 Supporting files

Supporting files refer additional XML files that are not directly part of the schema definition, but play important supporting roles. Examples include dictionary files that contain enhanced information on enumerations used in the standard, or common files that contain static elements that are commonly referred in CAAML files using XLink attributes.

The Snow Profile IACS standard only includes a single dictionary file.

3.3.1 Dictionary files

The observation element definitions in Snow Profile IACS are based on the International Classification for Seasonal Snow on the Ground (Fierz *et al.*, 2009). For example, the enumerations included in any `<grainForm>` elements include all grain shapes discussed in section 1.1 and Appendix A of Fierz *et al.* (2009). However, enumeration definitions in schema files do not contain any background information on the meaning of the information codes.

To make the definition of the information codes more accessible, the content of the International Classification for Seasonal Snow on the Ground (Fierz *et al.*, 2009) was encoded in a CAAML dictionary file. Dictionary files allow a more comprehensive encoding of enumeration definitions. The following code snippet illustrated the encoding of the additional information for two examples of grain shape entries.

```
<Dictionary gml:id="GrainShape">
	<description/>
	<identifier codeSpace="urn:IACS2009">GrainShape</identifier>
	<name>Grain Shape (Form)</name>
	<remarks>IACS document section 1.1 and appendix A </remarks>
	<dictionaryEntry>
		<Definition gml:id="GrainShapePP">
			<description/>
			<identifier codeSpace ="urn:IACS2009">PP</identifier>
			<name>Precipitation Particles</name>
			<symbolRef xlink:href=""/>
		</Definition>
	</dictionaryEntry>
	<dictionaryEntry>
		<Definition gml:id="GrainShapePPco">
```

```
                <description>Prismatic crystal, solid or hollow</description>
                <identifier codeSpace="urn:IACS2009">PPco</identifier>
                <name>Precipitation Particles - Columns</name>
                <symbolRef xlink:href=""/>
            </Definition>
        </dictionaryEntry>
        ...
</Dictionary>
```

Enumerations included in the Snow Profile IACS standard are the identifiers of each `<Definition>` elements within a given `<Dictionary>` element. The code snippet below show the related type definition for the GrainFormBaseType in the Snow Profile IACS schema file

```
<simpleType name="GrainFormBaseType">
    <annotation>
        <documentation>Enumerations extracted from CAAML encoded IACS 2009 ↵
                standard document</documentation>
    </annotation>
    <restriction base="string">
        <enumeration value="PP"/>
        <enumeration value="PPco"/>
        ...
    </restriction>
</simpleType>
```

Possible applications for this dictionary file include the population of dropdown lists or help menus for categorical observation elements defined in applications that follow the IACS standard. The dictionary file for the Snow Profile IACS standard is available at http://caaml.org/Schemas/V5.0/Profiles/SnowProfileIACS/Dictionary_IACS.xml.

3.3.2 Common files

There are no common files included in the Snow Profile IACS standard.

3.4 Technical details

A detailed technical documentation of the CAAML V5.0 Snow Profile IACS standard is available at http://caaml.org/Schemas/V5.0/Profiles/SnowProfileIACS/Doc/.

The following sections primarily provide a quick overview and focus on encoding aspects that might not be obvious from the above technical documentation.

3.4.1 Root element

The root tag in a snow profile CAAML file is the `<SnowProfile>` element. This element has four mandatory child properties:

- `<metaDataProperty>`
  This property element contains metadata about the observations including information on the observer and the associated organisation.

- <validTime>
  The time of a snow profile observation can either be encoded as a time instant or a time period.
- <snowProfileResultsOf>
  This is the property element that contains the actual snow profile observations.
- <locRef>
  The location reference element includes the <ObsPoint> object element, which contains all geographic information about the location of the snow profile.

3.4.2 Snow profile observations

The container element for all meteorological and nivological observations within a snow profile is the <SnowProfileMeasurements> object element. In addition to the simple meteorological and snow surface observation property elements, such as <skyCond> or <airTempPres>, the <SnowProfileMeasurements> object contains the following complex elements:

- <stratProfile>
  for the traditional stratigraphic snow profile consisting of individuals layers.
- <tempProfile>
  for a layer independent temperature profile consisting of a series of individual point observations.
- <densityProfile>
  for a density profile independent of the main stratigraphic snow profile encoded within the <stratProfile> element.
- <lwcProfile>
  for a liquid water content profile independent of the main stratigraphic snow profile encoded within the <stratProfile> element.
- <specSurfAreaProfile>
  for a profile of specific surface area independent of the main stratigraphic snow profile encoded within the <stratProfile> element. Either consists of a series of layers or a tuples list of point observations in the case of large amounts of data.
- <hardnessProfile>
  for a hardness profile independent of the main stratigraphic snow profile encoded within the <stratProfile> element. Either consists of a series of layers or a tuples list of point observations in the case of large amounts of data.
- <stbTests>
  for results of snow stability tests

The following sections will briefly explain the most important encoding conventions for the different complex observation elements.

All of the above profiles contain strategically placed <customData> elements to allow for the encoding of additional observations or settings not included in the Snow Profile IACS standard (see 4.1 for more details on this topic).

3.4.2.1 Depth measurements

All depth measurements in a CAAML snow profile are in cm and always from top down as specified in the fixed dir attribute of the <SnowProfileMeasurements> element. The origin for the axis for depth values (0 cm) is at the snow surface.

The various depth measurements included in the <SnowProfileMeasurements> element, are:

- <hS>
  Overall height of snowpack at study site measured from snow surface to ground, that is the base in Fierz *et al.* (2009).
- <profileDepth>
  Depth of snow profile measured from the snow surface to the bottom of the snow pit
- <***Profile><Layer><depthTop>
  Depth of the top boundary of a layer in a layer profile.
- <***Profile><Layer><thickness>
  Thickness of a layer in a layer profile.
- <***Profile><Obs><depth>
  Depth of a point observation within a snow profile.

Figure 2 illustrates the relationship among the various depth measurements.

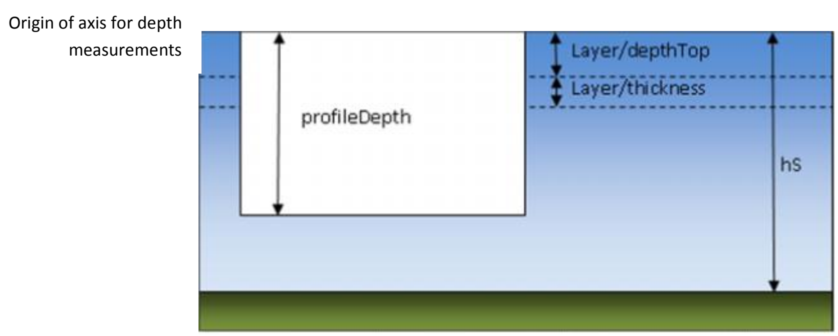

Figure 2: Depth measurements in snow profile observations

3.4.2.2 Stratigraphic profile

The <stratProfile> property element contains the traditional layer profile consisting of a series of layers. Only one stratigraphic layer profile is allowed per CAAML file. The CAAML snippet below provides an example of layer profile.

```
<stratProfile>
      <Layer>
            <comment>Some comment about this layer</comment>
            <depthTop uom="cm">0</depthTop>
            <thickness uom="cm">0.5 </thickness>
            <grainFormPrimary>FC</grainFormPrimary>
            <grainFormSecondary>SH</grainFormSecondary>
            <grainSize uom="mm">
                  <Components>
                        <avg>0.5</avg>
```

```
                <avgMax>1.5</avgMax>
            </Components>
        </grainSize>
        <validFormationTime>
            <TimePeriod>
                <beginPosition>2011-01-01</beginPosition>
                <endPosition>2011-01-05</endPosition>
            </TimePeriod>
        </validFormationTime>
        <hardness>F-4F</hardness>
        <lwc uom="">D</lwc>
        <density uom="kgm-3">250</density>
        <impurities>
            <Impurity>
                <description>Volcanic ash</description>
                <massFraction uom="ppm">0.001</massFraction>
            </Impurity>
        </impurities>
    </Layer>
    <Layer>
        ...
    </Layer>
    ...
</stratProfile>
```

The only required element within the <layer> element is <depthTop>, which describes the depth of the top of the layer measured from the snow surface. Interfaces without a thickness can be encoded by omitting the <thickness> element.

In addition to information about grain forms and sizes, the <Layer> element also contains property elements for layer averaged measurements of hardness, liquid water content and density. However, if these measurements are taken independently of the stratigraphic layers, it is more appropriate to encode them in their respective profile object elements (see, 3.4.2.4, 3.4.2.5, and 3.4.2.7).

The <validFormationTime> offers a mechanism for encoding the time instant or time period associated with the formation on the layer. While the duration of the formation of snow layers that took place over multiple days is encoded as a <TimePeriod>, the formation time of layers that formed within a day should be encoded as a <TimeInstant>.

The <impurities> property element allows the encoding of the mass fraction of multiple impurities in either % or ppm.

The <comment> element can be used to include a general comment.

3.4.2.3 Temperature profile

Temperature profiles are generally taken independently of the stratigraphic layers. The following CAAML snippet illustrates how temperature profile information is encoded.

```
<tempProfile uomDepth="cm" uomTemp="degC">
    <Obs>
```

```
            <depth>0.0</depth>
            <snowTemp>-10.7</snowTemp>
      </Obs>
      <Obs>
            <depth>4.0</depth>
            <snowTemp>-11.1</snowTemp>
      </Obs>
      ...
</tempProfile>
```

Each <snowTemp> observation is combined with a <depth> measurement and bracketed by an <Obs> element. The unit attributes are fixed at cm for depth and degrees Celsius for snow temperature. An optional <comment> tag can be included under the <Obs> element to encode an observation specific comment.

A snow surface temperature observation is encoded by specifying the associated <depth> of the observation as zero (see example above).

An observation of the present air temperature is encoded separately in the <airTempPres> element directly under the <SnowProfileMeasurements> element.

3.4.2.4 Density profile

The density profile uses the same encoding pattern as the stratigraphic profile, but the observation property elements are limited to the <density> element. The fixed unit for density measurements is kgm^{-3}.

```
<densityProfile uomDepthTop="cm" uomThickness="cm" uomDensity="kgm-3">
      <Layer>
            <depthTop>0.0</depthTop>
            <thickness>4.0</thickness>
            <density>188.0</density>
      </Layer>
      <Layer>
            <depthTop>4.0</depthTop>
            <thickness>17.0</thickness>
            <density>171.0</density>
      </Layer>
      ...
</densityProfile>
```

An optional <comment> tag can be included under the <Layer> element to encode an observation specific comment.

3.4.2.5 Liquid water content profile

The density profile uses the same encoding pattern as the stratigraphic profile, but the observation property elements are limited to the <lwc> element. The fixed unit for the liquid water content measurement is 'percent per volume'.

```
<lwcProfile uomThickness="cm" uomDepthTop="cm" uomLwc="% per Vol">
      <Layer>
```

```
            <depthTop>0.0</depthTop>
            <thickness>4.0</thickness>
            <lwc>3.0</lwc>
      </Layer>
      <Layer>
            <depthTop>4.0</depthTop>
            <thickness>100.0</thickness>
            <lwc>0.0</lwc>
      </Layer>
      ...
</lwcProfile>
```

An optional <comment> tag can be included under the <Layer> element to encode an observation specific comment.

3.4.2.6 Specific surface area profile

The Snow Profile IACS standard supports two different ways of encoding a specific surface area profile. Profiles with a limited number of observations can be encoded with a layer profile similar to the density or liquid water content profile (3.4.2.4 and 3.4.2.5). However, for profiles with a large number of observation, this method of encoding becomes extremely verbose. A more efficient way to encode a large amount of information is a tuple list as illustrated in the following CAAML snippet.

```
<specSurfAreaProfile uomThickness="cm" uomDepthTop="cm" uomSpecSurfArea="m2kg-1">
      <MetaData>
            <methodOfMeas>Measurement Method</methodOfMeas>
            <uncertaintyOfMeas uom="m2kg-1">0.001</uncertaintyOfMeas>
      </MetaData>
      <MeasurementComponents>
            <depth>template</depth>
            <specSurfArea>template</specSurfArea>
      </MeasurementComponents>
      <Measurements>
            <tupleList>1.0, 68.3 2.0, 44.7 ... </tupleList>
      </Measurements>
</specSurfAreaProfile>
```

The components of the tuple list are specified within the <MeasurementComponents> element, which lists them in order. The fixed 'template' value is used to indicate that the property element is only a placeholder.

The actual observations are encoded in a tuple list in the <tupleList> tag under the <Measurements> element. While the individual values of a tuple are separated by a comma (,), the tuples are space (' ') delimited. There is no limit on the number of tuples that can be included in such a tuples list.

In addition to the measurements, the <specSurfAreaProfile> element includes an optional <MetaData> element that allows the encoding of background information including the measurement method (<methodOfMeas>) and the uncertainty of the measurement (<uncertaintyOfMeas>).

3.4.2.7 Hardness profile

While the <SnowProfileMeasurements> element only supports single profiles for temperature, density, liquid water content and specific surface area, it is possible to include multiple hardness profiles. This functionality was included to support the effective encoding of multiple snow micro penetrometer measurements with a single stratigraphic profile.

Traditional hand hardness profiles are best encoded within the stratigraphic layer profile element <stratProfile> (see 3.4.2.2).

For the encoding of specific hardness profiles, the Snow Profile IACS standard supports a layer type as well as a tuples list type format similarly to the specific surface area profile.

Similar to the specific surface area profile, the <hardnessProfile> element includes a <MetaData> element that allows the encoding of background information. The possible values of the mandatory <methodOfMeas> element are 'Snow Micro Pen', 'Ram Sonde', 'Push Pull Gauge' and 'Other'. In addition, the <MetaData> element includes the optional <surfOfIndentation> element.

Ram hardness or push-pull-gauge profiles with a limited number of observations are best encoded using a layer profile format, similar to the density and liquid water content profile (3.4.2.4 and 3.4.2.5).

```
<hardnessProfile uomHardness="N" uomThickness="cm" uomDepthTop="cm" ⮰
          uomWeightHammer="kg" uomWeightTube="kg" uomDropHeight="cm">
     <MetaData>
          <methodOfMeas>Ram Sonde</methodOfMeas>
     </MetaData>
     <Layer>
          <depthTop>0.0</depthTop>
          <thickness>22.0</thickness>
          <hardness>10.0</hardness>
          <weightHammer>0.0</weightHammer>
          <weightTube>1.0</weightTube>
          <nDrops>0</nDrops>
          <dropHeight>0.0</dropHeight>
     </Layer>
     <Layer>
          <depthTop>22.0</depthTop>
          <thickness>0.0</thickness>
          <hardness>20.0</hardness>
          <weightHammer>1.0</weightHammer>
          <weightTube>1.0</weightTube>
          <nDrops>0</nDrops>
          <dropHeight>0.0</dropHeight>
     </Layer>
     <Layer>
          <depthTop>22.0</depthTop>
          <thickness>4.0</thickness>
          <hardness>320.0</hardness>
          <weightHammer>1.0</weightHammer>
          <weightTube>1.0</weightTube>
```

```
            <nDrops>6</nDrops>
            <dropHeight>20.0</dropHeight>
      </Layer>
      ...
</hardnessProfile>
```

While the attributes uomHardness, uomThickness and uomDepthTop are mandatory for all measurement methods, the optional attributes uomWeightHammer, uomWeightTube and uomDropHeight are only required to specify the units of the additional observation elements related to ram sonde measurements.

However, this method of encoding is too verbose for large amounts of data normally collected by snow micro penetrometer. A more efficient way to encode a large amount of information is a tuple list similar to the specific surface area profiles. An example of the tuple list encoding is given in the CAAML snippet below.

```
<hardnessProfile uomHardness="N" uomThickness="cm" uomDepthTop="cm">
      <MetaData>
            <methodOfMeas>Snow Micro Pen</methodOfMeas>
            <surfOfIndentation uom="m2">0.00002</surfOfIndentation>
      </MetaData>
      <MeasurementComponents>
            <depth>template</depth>
            <penRes>template</penRes>
      </MeasurementComponents>
      <Measurements>
            <tupleList>0.1, 0.10 0.2, 0.25 ... </tupleList>
      </Measurements>
</hardnessProfile>
```

The components of the tuple list are specified within the <MeasurementComponents> element, which lists them in order. The fixed 'template' value is used to indicate that the property element is only a placeholder.

The actual observations are encoded in a tuple list in the <tupleList> tag under the <Measurements> element. While the individual values of a tuple are separated by a comma (,), the tuples are space (' ') delimited. There is no limited on the number of tuples that can be included in such a tuples list.

3.4.2.8 Stability tests

The Snow Profile IACS standard currently supports four different stability tests

- Compression Test <ComprTest>
- Extended Column Test <ExtColumnTest>
- Rutschblock Test <RBlockTest>
- Shear Frame Test <ShearFrameTest>
- Propagation Saw Test <PropSawTest>

The <stbTests> property element can contain an unlimited number of individual test results.

The encoding of the stability test results follows the same pattern for all four stability test type. The CAAML snippet below illustrates the encoding of a no failure result of a Rutschblock Test.

```
<RBlockTest>
      <comment>Some comment about test</comment>
      <noFailure/>
</RBlockTest>
```

The <noFailure/> property element is an empty XML tag that simply indicates a no failure result by its presence.

A failure result of a Compression Test is encoded as follows.

```
<ComprTest>
      <comment>Some comment about test</comment>
      <failedOn>
            <Layer>
                  <depthTop uom="cm">53.0</depthTop>
            </Layer>
            <Results>
                  <fractureCharacter>BRK</fractureCharacter>
                  <testScore>24</testScore>
            </Results>
      </failedOn>
</ComprTest>
```

In case the test results are not accompanied by a full stratigraphic layer profile, the <Layer> object elements can also include the <thickness>, <grainFormPrimary>, <grainFormSecondary>, <grainSize> and <validFormationTime> elements.

Compression Test

For the Compression Test, the <testScore> can contain the following values (CAA, 2007, AAA, 2010):

- Numerical values from **1 to 30** to indicate number of taps until failure
- **CTV** (Very Easy) for fractures occurring during cutting of column
- **CTE** (Easy) for fractures occurring before 10 light taps using finger tips only
- **CTM** (Moderate) for fracture occurring before 10 moderate tabs from elbow using finger tips
- **CTH** (Hard) for fractures occurring before 10 firm taps from whole arm using palm or fist

CTN (No fracture) is encoded with the <noFailure/> property element.

Extended Column Test

For the Extended Column, the <testScore> can contain the following values (Simenhois and Birkeland, 2009; AAA, 2010):

- **ECTPV** for a fracture that propagates across the entire column through the weak layer or interface during isolation
- **ECTP1 to ECTP30** for fractures that initiate and propagate across the entire column through the weak layer or interface on the ## tap *or* fractures that initiate on the ## tap and propagate across the column on the ##+1 tap
- **ECTN1 to ECTN30** for fractures that initiate on the ## tap but does not propagate across the entire column through the weak layer or interface on either the ## or the ##+1 tap

Similar to all other stability tests, **ECTX** (no fracture occurs in the weak layer during the test) is encoded with the <noFailure/> property element.

Rutschblock Test

For the Rutschblock Test, the <testScore> can contain the following values (CAA, 2007; AAA, 2010):

- **RB1**: The block slides during digging or cutting, or any time before the block is completely isolated.
- **RB2**: Tester approaches the block from above and gently steps down onto the upper part of the block (within 35 cm of the upper wall).
- **RB3**: Without lifting the heels, tester drops once from straight leg to bent knee position (feet together), pushing downwards compacting surface layers.
- **RB4**: Tester jumps up and lands in the same compacted spot.
- **RB5**: Tester jumps again onto the same compacted spot.
- **RB6**: For hard or deep slabs, remove skis or snowboard and jump on the same spot. For soft or thin slabs where removing without equipment might penetrate through the slab, keep equipment on, step down another 35 cm (almost mid-block) and push once and then jump three times.

Similar to all other stability tests, **RB7** (none of the loading steps produces a smooth slope-parallel fracture) is encoded with the <noFailure/> property element.

Propagation Saw Test

Since the Propagation Saw Test is always targeted at a specific weak layer, all results of this test are encoded using the <failedOn> property element. An example of an encoded test result for the propagation saw test is given below.

```
<PropSawTest>
	<comment>Some comment about test</comment>
	<failedOn>
		<Layer>
```

```
                <depthTop uom="cm">53.0</depthTop>
            </Layer>
            <Results>
                <fracturePropagation>End</fracturePropagation>
                <cutLength>50</cutLength>
                <columnLength>100</columnLength>
            </Results>
        </failedOn>
</PropSawTest>
```

Possible enumerations for the <fracturePropagation> property element are 'Arr' (arrest), 'SF' (slab fracture) or 'End' (propagation to the end of the column) (AAA, 2010).

3.4.3 Location Information

All of the geographic information relevant for a snow profile is encoded in the <ObsPoint> object element. The following CAAML snippet illustrates a complete encoding of location information within the <locRef> property element.

```
<locRef>
    <ObsPoint gml:id="SLF7242_1">
        <description>Gaudergrat Nordhang - Parsenn - Klosters</description>
        <name>Gaudergrat</name>
        <obsPointSubType>Snowprofile Site</obsPointSubType>
        <validElevation>
            <ElevationPosition uom="m">
                <position>2260</position>
            </ElevationPosition>
        </validElevation>
        <validAspect>
            <AspectPosition>
                <position>N</position>
            </AspectPosition>
        </validAspect>
        <validSlopeAngle>
            <SlopeAnglePosition uom="deg">
                <position>36</position>
            </SlopeAnglePosition>
        </validSlopeAngle>
        <pointLocation>
            <gml:Point srsDimension="2" srsName="urn:ogc:def:crs:OGC:1.3:CRS84" ↵
                    gml:id="SLF7242_2">
                <gml:pos>9.796717652386688 46.85661559753197</gml:pos>
            </gml:Point>
        </pointLocation>
    </ObsPoint>
</locRef>
```

3.4.3.1 Mandatory location elements

The mandatory aspects of an <ObsPoint> include:

- A file-wide unique id in the gml:id attribute.
- A meaningful name of the location in the <name> property element.

- A meaningful observation subtype in the <obsPointSubType> property element. This element was derived from the subtype attribute used in GIS to distinguish among different type of locations within the four main location types of CAAML (Observation Point, Route, Slope, Region). Examples of possible subtypes for observation points are weather site, accident site, or study plot. Since the possible list of subtypes depends on the local operation, the Snow Profile IACS does not include a list of enumerations for this element. While the element is required, it is possible to leave it empty.

3.4.3.2 Location coordinates

Location coordinates of the snow pit location can be encoded within the <pointLocation> property element, which contains the <gml:Point> object element. All coordinates need to be encoded in decimal longitude and latitude values. The fixed value of the srsName attribute (`urn:ogc:def:crs:OGC:1.3:CRS84`) represents the Universal Resource Name (URN) of the WGS 84 longitude-latitude coordinate system within the OGC namespace.

4 Additional consideration

In this section, we discuss additional aspects for the encoding of information within CAAML in general and the Snow Profile IACS standard in particular.

4.1 Application specific information or new observations

The observation elements defined in the CAAML profile Snow Profile IACS represent core snow profile information independent of applications. The goal of the standard is to facilitate the broad exchange of information across application boundaries by separating information from presentation.

However, users and developers might find it useful to include additional information in their CAAML files that is not (or not yet) defined in the standard. Snow Profile IACS therefore allows the encoding of additional information in designated <customData> property element that are strategically placed within the CAAML standard. The content of the <customData> property element is not evaluated when a CAAML file is validated against the Snow Profile IACS schema files.

The code snippet below illustrates how the <customData> element can be used for encoding application specific information, such as the shading color for a specific layer in the stratigraphic profile.

```
<Layer>
     <customData>
          <app:SnowProfileSoftwareInfo>
               <app:fillColor>Red</app:fillColor>
               <app:outlineColor>Black</app:outlineColor>
               <app:hatchingCode>1</app:hatchingCode >
          </app:SnowProfileSoftwareInfo>
     </customData>
     <depthTop uom="cm">0</depthTop>
     <thickness uom="cm">0.5 </thickness>
     <grainFormPrimary>FC</grainFormPrimary>
</Layer>
```

The content of the <customData> property element needs to reside in a non-CAAML namespace.

The mechanism of the <customData> property element has likely two main applications:

- The encoding of software specific information regarding the presentation of snow profile information. If developers of snow profile programs agree on the XML format of this information, it would be possible to exchange this information across programs as well.

- An experimental platform for the encoding of additional and/or research specific snow profile observations that have not yet been considered for inclusion in the Snow Profile IACS standard. Once these observations are established among the wider community, they will be incorporated in the Snow Profile IACS schema files during the next scheduled revision of the standard.

4.2 Date and Time

Numerous elements in CAAML require the encoding of date and time values. Date and time values in CAAML are restricted to the following two date and time formats

- Simple date in the format of YYYY-MM-DD (e.g., 2011-01-05)
- Complete date and time including the offset to UTC time as an indicator for the time zone. The general format is YYYY-MM-DDThh:mm:ss+/-nh:nm (e.g., 2011-01-05T14:00-08:00)

4.3 Single value versus range of values

Numerous observations encoded in CAAML can either have single values or cover a range of values. Examples include observation time, elevation, aspect and incline. The encoding of all of these observations follow the same pattern and naming convention. In case of elevation, a single elevation is encoded as follows

```
<validElevation>
	<ElevationPosition uom="m">
		<position>2260</position>
	</ElevationPosition>
</validElevation>
```

An elevation range from 1000 m to 2000 m is encoded as

```
<validElevation>
	<ElevationRange uom="m">
		<beginPosition>1000</beginPosition>
		<endPosition>2000</endPosition>
	</ElevationRange>
</validElevation>
```

One sided elevation ranges, such as higher than 1000 m or below 2000 m can be encoded by either omitting the <endPosition> or <beginPosition> element respectively.

In the Snow Profile IACS standard many of these observations are restricted to single values. However, the encoding structure was maintained for compatibility reasons.

5 Useful references

American Avalanche Association, 2010. *Snow, Weather, and Avalanches: Observational Guidelines for Avalanche Programs in the United States.*, 152 pp. [available online at http://www.american avalancheassociation.org/pub_swag.php]

Canadian Avalanche Association. (2007). *Observation Guidelines and Recording Standards for Weather, Snowpack, and Avalanches*. Revelstoke, BC.

Fierz, C., Armstrong, R.L., Durand, Y., Etchevers, P., Greene, E., McClung, D.M., Nishimura, K., Satyawali, P.K. and Sokratov, S.A. 2009. *The International Classification for Seasonal Snow on the Ground.* IHP-VII Technical Documents in Hydrology N°83, IACS Contribution N°1, UNESCO-IHP, Paris.

Burggraf, D. S. (2003). GML Foundation Project Developing and Managing GML Application Schemas: A Best Practices Guide prepared by Galdos Systems Inc. (No. TR2003-232-01). Vancouver, BC: Galdos Systems Inc..

Lake, R., Burggraf, D. S., Trninic, M., & Rae, L. (2004). *GML Geographic Mark-Up Language: Foundation for the Geo Web*. Etobicoke, ON: Wiley.

Simenhois, R., & Birkeland, K. W. (2009). The Extended Column Test: Test effectiveness, spatial variability, and comparison with the Propagation Saw Test. *Cold Regions Science and Technology*, *59*(2-3), 210-216.