# Creating a Holocene-prehistoric Inventory of Volcanological Features Groups

## Towards Sustainable Multi-disciplinary Context Integration in Prehistory and Archaeology Based on the Methodology of Coherent Conceptual Knowledge Contextualisation

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***Abstract*—This paper presents research on a practical solution for geoscientific inventories based on conceptual contextualisation. The goal of this research is the creation of a practical Holocene-prehistoric inventory of worldwide volcanological features groups, coherently integrating multi-disciplinary conceptual knowledge. The focus is a sustainable multi-disciplinary integration of knowledge contexts, especially from prehistory and archaeology, which further enables coherent conceptual knowledge contextualisation and georeferenced symbolic representation. This paper provides implementations and realisations of the coherent conceptual knowledge and the methodological component integration. The resulting inventory is illustrated by excerpts of two features groups based on a conceptual knowledge result matrix. Future research will address the resulting Holocene-prehistoric inventory of worldwide volcanological features, continuous development of resources and integration and coherent conceptual knowledge contextualisation with prehistorical and archaeological knowledge resources.**

***Keywords–Prehistory; Holocene; Coherent Multi-disciplinary Conceptual Knowledge Integration; CKRI; CRI Framework.***

## I. Introduction

The goal of this research is the creation of a practical Holocene-prehistoric inventory of worldwide volcanological features groups, integrating arbitrary coherent conceptual knowledge. The target is a sustainable multi-disciplinary integration of knowledge contexts, especially from prehistory and archaeology, which further enables a coherent conceptual knowledge contextualisation and georeferenced symbolic representation. The approach conforms with information science fundaments and universal knowledge, which enable an integration of the required components from methodologies to realisations for knowledge representations of realia and abstract contexts [1], considering that many facets of knowledge, including prehistory, need to be continuously acquired and reviewed [2]. Creating contextualisation requires to coherently integrate multi-disciplinary knowledge and to enable symbolic representations, e.g., integrating chorological and chronological contexts. Realisations need to integrate a wide range of components as required from participating disciplines, e.g., for dynamical processing, geoprocessing, spatial contextualisation. Implementation and realisation based on the methodology of coherent conceptual knowledge contextualisation requires the integration of standardised, modular components required for task within participating disciplines. This research employs knowledge resources, data sources, and Points of Interest (PoI), especially Knowledge Resources (KR) focussing on volcanological features, prehistory, and archaeology.

Therefore, two major reference implementations were deployed for implementation, realisation, and continuous further development. The coherent knowledge resources and the practical realisation are fully based on the main implementations of the prehistory-protohistory and archaeology Conceptual Knowledge Reference Implementation (CKRI) [3] and the Component Reference Implementations (CRI) framework [4]. CKRI provides the knowledge framework, including multi-disciplinary contexts of natural sciences and humanities [5]. CRI provides the required component groups and components for the implementation and realisation of all the procedural modules. The component and workflow procedure related research for this inventory is in focus of multi-disciplinary research groups and matter to be reported in separate publications. Many aspects of knowledge [6], including meaning, can be described using knowledge complements supporting a modern definition of knowledge [7] and subsequent component instrumentation, e.g., considering factual, conceptual, procedural, metacognitive, and structural knowledge. Knowledge complements are a means of understanding and targeting new insight, e.g., enabling advanced contextualisation, integration, analysis, synthesis, innovation, prospection, and documentation. Regarding knowledge, it should be taken for granted, that scientific members of any disciplines nowerdays continuously practice and train themselves in development and practical employment of methods, algorithms, and components as required by their disciplines and keep track with how to integrate methods. The reference implementations are part of the developments and provide sustainable, flexible, and efficient fundaments for solutions targeting the creation of coherent multi-disciplinary conceptual knowledge contextualisation.

The rest of this paper is organised as follows. Section II presents the methodological implementation and realisation with the CKRI references and the respective component integration for this research. Section III shows the resulting inventory, the knowledge integration results, and excerpts of the created volcanological features groups of the inventory. Section IV provides a compact discussion of the results regarding the coherent conceptual knowledge integration. Section V summarises lessons learned, conclusions, and future work.

## II. Methodological implementation and realisation

Implementation and realisation are based on the CKRI reference implementation [3], and respective contextualisation. Components outside the core scope of this knowledge focussed geoscientific, prehistoric, and archaeological research are employed and can be extended via the CRI frame reference implementations [4]. Both provide sustainable fundaments for highest levels of reproducibility and standardisation.

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### A. Resulting coherent conceptual knowledge implementation

Universally consistent multi-disciplinary conceptual knowledge is based on the Conceptual Knowledge Reference Implementation (CKRI) [3] and implemented via UDC code references for demonstration, spanning the main tables [8] shown in Table I.

TABLE I. CKRI IMPLEMENTATION OF COHERENT CONCEPTUAL KNOWLEDGE CONTEXTUALISATION; MAIN TABLES (EXCERPT).

| *Code / Sign Ref.* | *Verbal Description (EN)* |
|---|---|
| **UDC:0** | Science and Knowledge. Organization. Computer Science. Information. Documentation. Librarianship. Institutions. Publications |
| **UDC:1** | Philosophy. Psychology |
| **UDC:2** | Religion. Theology |
| **UDC:3** | Social Sciences |
| **UDC:5** | Mathematics. Natural Sciences |
| UDC:52 | Astronomy. Astrophysics. Space research. Geodesy |
| UDC:53 | Physics |
| UDC:539 | Physical nature of matter |
| UDC:54 | Chemistry. Crystallography. Mineralogy |
| UDC:55 | Earth Sciences. Geological sciences |
| UDC:550.3 | Geophysics |
| UDC:551 | General geology. Meteorology. Climatology. Historical geology. Stratigraphy. Palaeogeography |
| UDC:551.21 | Vulcanicity. Vulcanism. Volcanoes. Eruptive phenomena. Eruptions |
| UDC:551.2... | Fumaroles. Solfataras. Geysers. Hot springs. Mofettes. Carbon dioxide vents. Soffioni |
| UDC:551.44 | Speleology. Caves. Fissures. Underground waters |
| UDC:551.46 | Physical oceanography. Submarine topography. Ocean floor |
| UDC:551.7 | Historical geology. Stratigraphy |
| UDC:551.8 | Palaeogeography |
| UDC:56 | Palaeontology |
| **UDC:6** | Applied Sciences. Medicine, Technology |
| **UDC:7** | The Arts. Entertainment. Sport |
| **UDC:8** | Linguistics. Literature |
| **UDC:9** | Geography. Biography. History |
| UDC:902 | Archaeology |
| UDC:903 | Prehistory. Prehistoric remains, artefacts, antiquities |
| UDC:904 | Cultural remains of historical times |

The CKRI is provided in development stage editions, prehistory-protohistory and archaeology E.0.4.6, natural sciences E.0.2.8). Table II shows an excerpt of consistent multi-disciplinary conceptual knowledge based on UDC code references spanning auxiliary tables [9].

TABLE II. CKRI IMPLEMENTATION OF COHERENT CONCEPTUAL KNOWLEDGE CONTEXTUALISATION; AUXILIARY TABLES (EXCERPT).

| *Code / Sign Ref.* | *Verbal Description (EN)* |
|---|---|
| **UDC (1/9)** | Common auxiliaries of place |
| UDC:(23) | Above sea level. Surface relief. Above ground generally. Mountains |
| **UDC:"..."** | Common auxiliaries of time. |
| UDC:"6" | Geological, archaeological and cultural time divisions |
| UDC:"62" | Cenozoic (Cainozoic). Neozoic (70 MYBP - present) |
| UDC:"63" | Archaeological, prehistoric, protohistoric periods and ages |

The CKRI implementations provide the fundament for the coherent multi-disciplinary knowledge based integration and the realisations of the methodological component integration.

### B. Resulting methodological component integration

Integration components, reflecting standards and sustainable modules are based on the major groups of the Component Reference Implementations (CRI) frame [4]. The CRI framework is provided in development stage edition E.0.3.7. The ten major CRI component groups were integrated for the implementation and realisation of the practical Holocene-prehistoric inventory of volcanological features groups, especially:

1) Conceptual knowledge frameworks.
2) Conceptual knowledge base.
3) Integration of scientific reference frameworks.
4) Formalisation.
5) Methodologies and workflows integration.
6) Prehistory Knowledge Resources.
7) Natural Sciences Knowledge Resources.
8) Inherent representation groups.
9) Scientific context parametrisation.
10) Structures and symbolic representation.

Focus is on the contextualisation and conceptual knowledge framework, its development, and its flexibility of integration with advanced components. Relevant pre-existing and ongoing component developments addressing knowledge with multi-disciplinary KR have been summarised [10]. Integration of components and procedural realisations are out of scope here but subject of research in respective fields. Procedural realisations will therefore be published separately.

The exact components for the implementation and realisation of the practical Holocene-prehistoric inventory of volcanological features groups are given in the next sections.

## III. RESULTING INVENTORY

The following sections provide illustrative object entity examples of the new practical Holocene-prehistoric inventory of volcanological features groups as implemented and realised integrating the aforementioned reference implementations.

### A. Resulting coherent conceptual knowledge integration

Table III shows an excerpt of the result matrix of Holocene-prehistoric volcanological features groups. The result matrix includes conceptual knowledge view groups [11] based on CKRI references [3], factual knowledge from the Knowledge Resources objects, and respective country codes.

The coherent conceptual knowledge integration enables a multi-disciplinary conceptual knowledge integration. This case demonstrates an integration of Holocene-prehistoric volcanological features, geoscientific knowledge, and spatial knowledge. Any further knowledge can be coherently integrated, e.g., prehistoric and archaeological knowledge.

The result matrices reflect the key assets with the CRI framework [4] to realise the inventory and symbolic representations and to enable a continuous development.

### B. Resulting symbolic representation of features groups

Figure 1 shows a resulting symbolic representation of a volcanological features group, strato volcano, as based on the coherent conceptual knowledge integration. Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas. Figure 2 shows a resulting symbolic

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TABLE III. RESULT MATRIX OF HOLOCENE-PREHISTORIC VOLCANOLOGICAL FEATURES GROUPS (EXCERPT). THE RESULT MATRIX INCLUDES CONCEPTUAL KNOWLEDGE VIEW GROUPS [11] (CKRI), KNOWLEDGE RESOURCES OBJECTS, AND COUNTRY CODES (EXCERPT).

| *Conceptual Knowledge View Group* | *Knowledge Resources Object* | *Country Code* |
|---|---|---|
| CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;“62”. . . | Agua de Pau | PT |
| CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;“62”. . . | Alngey | RU |
| CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;“62”. . . | Azuma | JP |
| CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;“62”. . . | Hekla | IS |
| CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;“62”. . . | . . . | . . . |
| CKRI: UDC:551.2. . .,551.21,550.3,(23),. . .MAARS_FEATURES;“62”. . . | Cerro Tujle | CL |
| CKRI: UDC:551.2. . .,551.21,550.3,(23),. . .MAARS_FEATURES;“62”. . . | Suoh | ID |
| CKRI: UDC:551.2. . .,551.21,550.3,(23),. . .MAARS_FEATURES;“62”. . . | Ukinrek Maars | US |
| CKRI: UDC:551.2. . .,551.21,550.3,(23),. . .MAARS_FEATURES;“62”. . . | West Eifel Volcanic Field | DE |
| CKRI: UDC:551.2. . .,551.21,550.3,(23),. . .MAARS_FEATURES;“62”. . . | . . . | . . . |

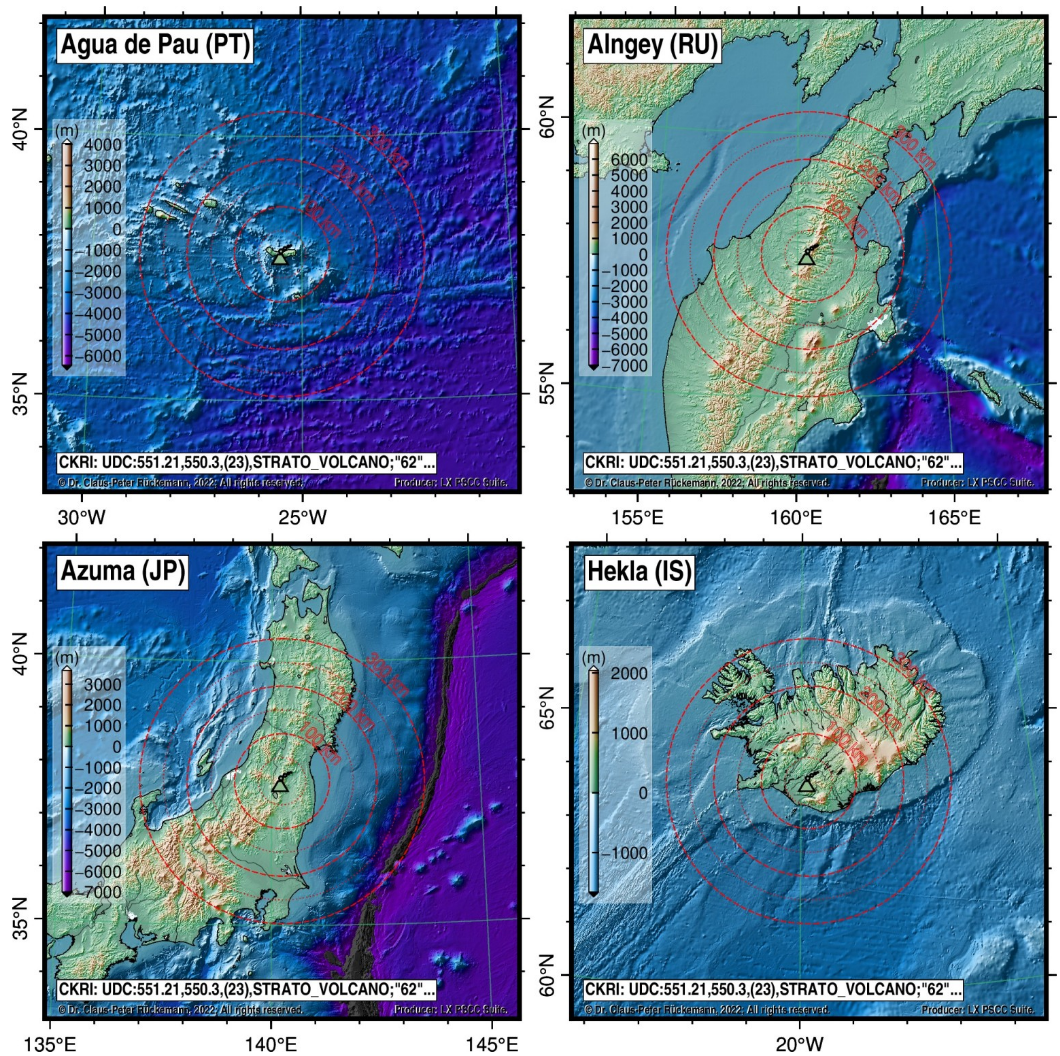


Figure 1. Resulting symbolic representation of a volcanological features group (strato volcano) based on coherent conceptual knowledge integration (excerpt). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.

representation of a volcanological features group, maars, as based on the coherent conceptual knowledge integration. The resulting symbolic representations reflect the coherent conceptual knowledge (CKRI, UDC references) and topographic and bathymetric knowledge (CRI components). Projection for all representations is Lambert Azimuthal Equal Area. Ellipsoid is World Geodetic System 84 (WGS-84). The conceptual knowledge references correspond with the symbolism, e.g., automatic assignment of symbols, e.g., volcano symbols or different colours for different volcanological features groups.

These features groups integrate topographic and bathymetric knowledge, for example. Here, available multi-disciplinary knowledge can be used for contextualisation, e.g., representing characteristics, physical properties, plate tectonics, soil, and age. The conceptual knowledge view groups of object entities of Holocene-prehistoric volcanological features groups correspond with the result matrix (Table III). Entities of each features group refer to any further available volcanological knowledge, e.g., factual knowledge. In these excerpts, the symbolic representations include the calculated object labels, calculated

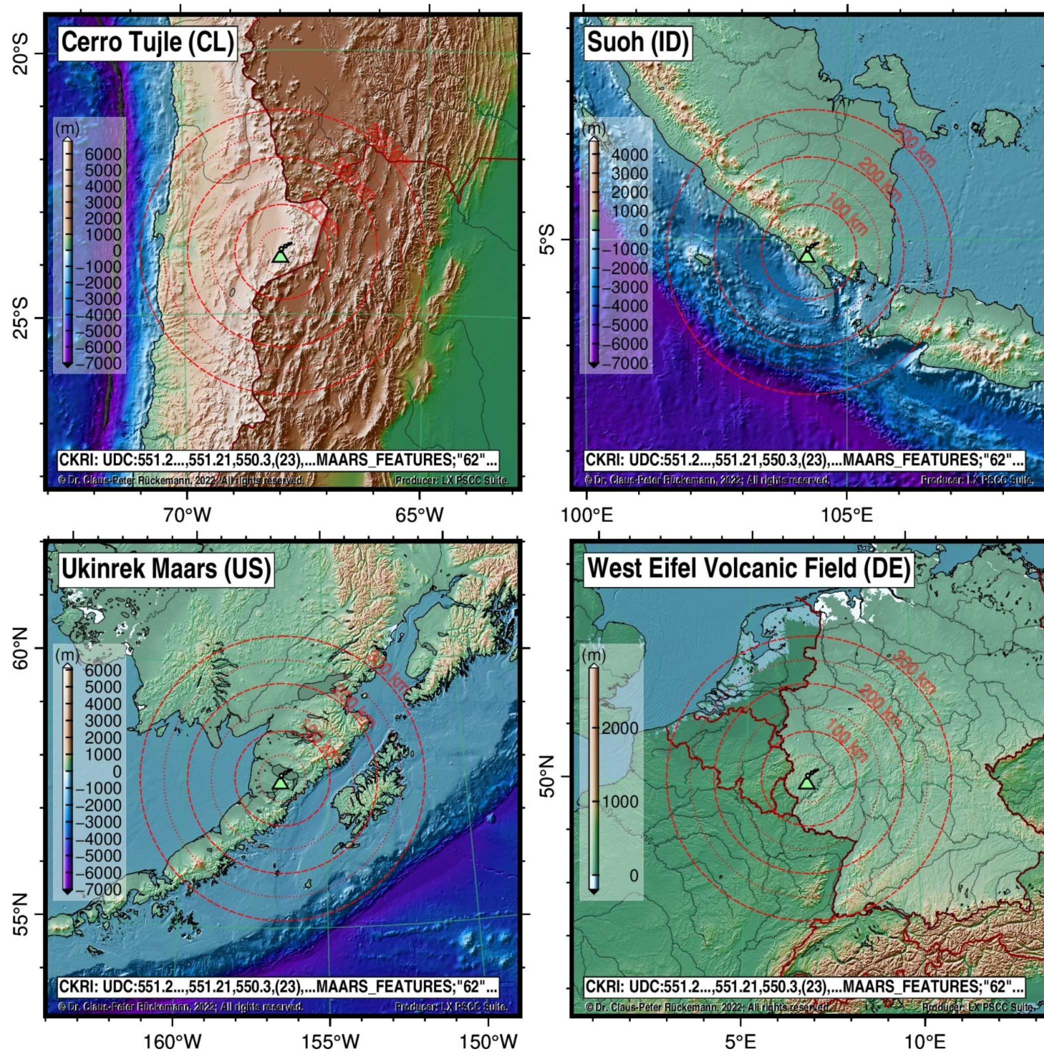


Figure 2. Resulting symbolic representation of a volcanological features group (maars) based on coherent conceptual knowledge integration (excerpt). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.

country codes, distance markers up to 300 km in 50 km steps, and calculated country height range of bathymetry/topography.

The generated symbolic representations can integrate most recent knowledge (e.g., factual, conceptual, procedural, metacognitive, structural) contributed by disciplines and can therefore consider multi-disciplinary results and findings in order to create conceptual knowledge references and new insight.

## IV. Components integrated for implementation and realisation

The following passages give a compact overview of major component implementations and development integrated with this research. More detailed, comprehensive discussion and examples regarding fundaments are available with the references on methodology, contextualisation, and conceptual knowledge.

The created and further developed reference implementations of conceptual knowledge frameworks (this research major references in Tables I and II) are used with the implementation and realisation *KR* [10].

Conceptual knowledge base is The *Universal Decimal Classification (UDC)* [11], a general plan for knowledge classification, providing an analytico-synthetic and *faceted* classification, designed for subject description and indexing of content of information resources *irrespective of the carrier, form, format, and language*. UDC-based references for demonstration are taken from the multi-lingual UDC summary [11] released by the UDC Consortium, Creative Commons license [12].

Relevant scientific practices, frameworks, and standards from disciplines and contexts are integrated with the Knowledge Resources, e.g., here details regarding volcanological features [13], chronologies, spatial information, and Volcanic Explosivity Index (VEI) [14].

All integration components, for all disciplines, require an *explicit and continuous formalisation* [15] *process*. The formalisation includes computation model support, e.g., *parallelisation standards, OpenMP* [16], Reg Exp patterns, e.g., *Perl Compatible Regular Expressions (PCRE)* [17].

*Methodologies for creating and utilising methods include model processing, remote sensing, spatial mapping, high information densities, and visualisation.* Respective contextualisation of (prehistoric) scenarios should each be done under specific (prehistoric) conditions, especially supported by state-of-the-art methods, e.g., spatial operations, triangulation, gradient computation, and projection.

The symbolic representation of the contextualisation can be done with a wide range of methods, algorithms, and available components, e.g., via LX Professional Scientific Content-Context-Suite (LX PSCC Suite) deploying the Generic Mapping Tools (GMT) [18] for visualisation.

Prehistoric objects and contexts are taken from *The Prehistory and Archaeology Knowledge Archive (PAKA)*, in continuous development for more than three decades [19] and is released by DIMF [20].

Several coherent systems of major natural sciences' context object groups from *KR realisations* have been implemented, especially Knowledge Resources focussing on volcanological features [14] deployed with in depth contextualisation [13] and with a wide range [11] of contexts [10] and structures [21].

The contextualisation for the inventory can employ state-of-the-art results from many disciplines, e.g., context from the natural sciences resources, integrating their inherent representation and common utilisation, e.g., *points*, *polygons*, *lines*, *Digital Elevation Model (DEM), Digital Terrain Model (DTM), and Digital Surface Model (DSM) representations* sources, e.g., from *satellites*, Unmanned Aerial Vehicles (UAV), *z-value representations*, *distance representations*, *area representations*, *raster*, *vector*, *binary*, and *non-binary data*. Employed resources are High Resolution (HR) (Space) Shuttle Radar Topography Mission (SRTM) [22] data fusion [23], HR Digital Chart of the World (DCW) [24], and Global Self-consistent Hierarchical High-resolution Geography (GSHHG) [25]. SRTM was produced under the National Aeronautics and Space Administration (NASA) Making Earth System Data Records for Use in Research Environments (MEaSUREs) program. The Land Processed Distributed Active Archive Center (LPDAAC), USA [26], operates as a partnership between the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA), USA, and is a component of NASA's Earth Observing System Data and Information System (EOSDIS). Resources are released by NASA and JPL Jet Propulsion Laboratory (JPL), USA, data [27] and site [28]. SRTM15 Plus [23] is continuously updated and improved [22].

Scientific *context parametrisation of prehistoric targets* can use the overall insight from all disciplines, e.g., parametrising algorithms and creating palaeolandscapes.

Structure is an organisation of interrelated entities in a material or non-material object or system [21]. Structure is essential in logic as it carries unique information. Structure means features and facilities. There are merely higher and lower facility levels of how structures can be addressed, which result from structure levels. Structure can, for example, be addressed by logic, names, references, address labels, pointers, fuzzy methods, phonetic methods. The deployment of long-term universal structure and data standards is essential. Relevant examples of sustainable implementations are *NetCDF* [29] based standards, including advanced features, hybrid structure integration, and parallel computing support (*PnetCDF*) and generic multi-dimensional table data, standard xyz files, universal source and text based structure and code representations.

## V. DISCUSSION

Implementation and realisation provide a coherent conceptual contextualisation and a seamlessly coherent conceptual knowledge integration with any available knowledge resources. The practical Holocene-prehistoric inventory of volcanological features groups shows important characteristics for multi-disciplinary knowledge space, e.g.:

- Coherent conceptual knowledge integration.
- Selection and coherent integration of resources.
- Flexible criteria for knowledge integration.
- High level of knowledge consistency.
- High level of reproducibility for workflows and results.
- Automated and semi-automated workflow creation.
- Consequent multi-language support (e.g., UDC).
- Deployment of structural knowledge.
- Deployment of available processing and filtering.
- Spatial integration and processing.
- Georeferencing, generic components and results.

Characteristics for component space are, e.g.:

- Dynamical integration of resources and workflows.
- Arbitrary numbers of contextualisation results.
- Flexible creation of workflows and parallelisation.
- Scalable realisation, e.g., parallelisation models.

Knowledge and its complements are interrelated with possible structures and the organisation of knowledge, which contributes to the facilities, which can be parametrised and deployed, e.g., flexibility of data locality and parallelisation. The reference implementation supports parallelisation, e.g., embarrassingly parallel procedures, e.g., via OpenMP [16] and job parallel procedures. The CRI framework components allow efficient parallelisations for any part of workflows and resources, e.g., parallel computation, processing, and generation of frames from satellite data including parallel deployment of Knowledge Resources for multi-dimensional model creation.

Each set of component integration can range from a few to millions of entities for each result group and in consequence millions of symbolic representations for integrated contexts. In the case of the practical Holocene-prehistoric inventory of volcanological features groups we create about 500–1000 basic object entity sets per context.

## VI. CONCLUSION

Employing the methodology of coherent conceptual knowledge classification for developing a coherent context integration in prehistory and archaeology proved efficient and sustainable. The goal of creating a practical Holocene-prehistoric inventory of worldwide volcanological features groups based on the CKRI and CRI framework was successful achieved and allows further coherent contextualisation with knowledge resources, especially for the integration and contextualisation of multi-disciplinary research in prehistory, archaeology, natural sciences, and humanities.

Future work will address the resulting and continuously further developed Holocene-prehistoric inventory of worldwide volcanological features, continuous resources development, coherent conceptual knowledge contextualisation and integration with prehistorical and archaeological knowledge resources, including further georeferencing and spatial processing.

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