Component Framework Implementation and Realisation for Development and Deployment of a Coherent Multi-disciplinary Conceptual Knowledge-based Holocene-prehistoric Inventory of Volcanological Features Groups and Faceting

Claus-Peter Rückemann
Westfälische Wilhelms-Universität Münster (WWU), Germany;
Unabhängiges Deutsches Institut für Multi-disziplinäre Forschung (DIMF), Germany;
Leibniz Universität Hannover, Germany
Email: ruckema@uni-muenster.de

***Abstract*—This paper presents extended insight in results and current status of the procedural component framework implementation and realisation for creation of a coherent multi-disciplinary conceptual knowledge-based Holocene-prehistoric inventory of worldwide volcanological features groups, especially enabled by conceptual knowledge facets. The goal is the creation of a sustainable framework of components, which can be employed for multi-disciplinary integration of knowledge contexts, especially from prehistory and archaeology. The component framework has to enable further coherent conceptual knowledge contextualisation and georeferenced symbolic representation. This paper provides the results on experiences of sustainable component integration and practical procedural implementations and realisations. Future research will address the creation of a component framework for a Holocene-prehistoric inventory of worldwide volcanological features, which enables coherent multi-disciplinary conceptual knowledge integration and contextualisation with prehistorical and archaeological knowledge resources.**

***Keywords*–Prehistory, Prehistoric Archaeology, and Holocene; Knowledge-based Contextualisation and Component Integration; Coherent Multi-disciplinary Conceptual Knowledge Faceting and Integration; CRI Framework; CKRI.**

I. INTRODUCTION

This paper is an extended and updated presentation of the research based on the publication and presentation at the INFOCOMP 2022 conference in Porto, Portugal [1]. Due to a number of requests for the created inventory, this extended paper concentrates on the practical inventory and procedural knowledge complements, showing a wider range of result groups based on practical facets used for on-demand contextualisation and symbolic representation.

The corresponding coherent complementary results and details on faceting from the research groups on multi-disciplinary conceptual knowledge [2] are further developed and have to be given in a separate publication [3]. That research concentrates on the conceptual knowledge reference implementation and realisation, the fundaments for creation of a multi-disciplinary coherent conceptual knowledge-based Holocene-prehistoric inventory of volcanological features groups along with the overall frame [4] and importance of information science methods and structures [5].

The overall multi-disciplinary contextualisation and faceting enables to integrate the state of the art scientific research results from respective disciplines on equal footing of knowledge and scientific level.

It can integrate a wide range of methodological approaches used in disciplines, e.g., conceptual knowledge based methods, chorology based methods, e.g., place described by conceptual knowledge and other factual knowledge like position, height, depth, chronology based methods, visualisation based methods, handling of multi-disciplinary contexts.

Coherent conceptual knowledge resources are results of often complex and long-term multi-disciplinary creation processes. Coherent conceptual knowledge resources may have to achieve an advanced level of implementation before procedural components can be created for sustainably employing these resources. The conceptual knowledge implementation for this inventory is in focus of multi-disciplinary research groups and matter to be reported in separate publications. Motivation is the creation of a sustainable and practical component framework based on coherent multi-disciplinary conceptual knowledge.

This paper presents the results of the procedural component framework implementation and realisation for creation of a coherent multi-disciplinary conceptual knowledge-based Holocene-prehistoric inventory of worldwide volcanological features groups, which are employing respective coherent knowledge resources. The goal of this research is the creation of a sustainable framework of components, which can be employed for multi-disciplinary integration of knowledge contexts, especially from prehistory and archaeology, too. The component framework further has to enable a coherent conceptual knowledge contextualisation and georeferenced symbolic representation.

The rest of this paper is organised as follows. Section II presents the major reference implementations. Section III presents the methodological implementation and realisation, workflow procedure, respective component reference implementation and integration and coherent conceptual knowledge implementation for the new inventory. Section IV discusses the procedural potential regarding integration of components, parallelisation, and implementation features. Section V summarises lessons learned, conclusions, and future work.

II. MAJOR REFERENCE IMPLEMENTATIONS

The coherent knowledge resources and the practical realisation are fully based on the Component Reference Implementations (CRI) framework [6], which is employing the main implementations of the prehistory-protohistory and archaeology Conceptual Knowledge Reference Implementation (CKRI) [7]. CRI provides the required component groups and components for the implementation and realisation of all the procedural modules. CKRI provides the knowledge framework, including multi-disciplinary contexts of natural sciences and humanities [8]. Both provide sustainable fundaments for highest levels of reproducibility and standardisation and allow continuous and consistent further development of discipline-centric and multi-discipline development of knowledge resources. Both reference implementations and all components are in continuous further development by the respective disciplines themselves.

The approach conforms with information science fundaments and universal knowledge and enables an integration of the required components from methodologies to realisations for knowledge representations of realia and abstract contexts [9], namely the Conceptual Knowledge Pattern Matching (CKPM) methodology, considering that many facets of knowledge, including prehistory, need to be continuously acquired and reviewed [10].

III. Methodological implementation and realisation

Implementation and realisation are based on the CKRI [7]. Components outside the core scope of this geoscientific, prehistoric, and archaeological research are employed and can be extended via the CRI frame [6].

The employed CKRI corresponds with development stage editions, prehistory-protohistory and archaeology E.0.4.8, natural sciences E.0.4.0). The CKRI implementations provide the fundament for the coherent multi-disciplinary knowledge based integration and the realisations of the methodological component integration. Integration components, reflecting standards and sustainable modules are based on the major groups of the Component Reference Implementations (CRI) frame [6]. The employed CRI framework corresponds with development stage edition E.0.3.9.

The conceptual knowledge implementation is the major practical knowledge-based result, a tool, which can be employed for enabling multi-disciplinary coherent knowledge-based contextualisation and solutions. The component framework provides integrated tools for realising solutions based on such multi-disciplinary coherent knowledge contextualisation.

The results and presentation are designed for multi-disciplinary audience willing to expand their methodological and practical facilities towards creating sustainable multi-disciplinary solutions deploying components, which can enable advanced coherent conceptual knowledge integration for knowledge-based projects. As employed for demonstration, the examples do not require expertise in volcanology but understanding and practical deployment may require the will to learn new methods, even naturally complex contexts, and advanced components, enabling fundaments and facilities.

The following implementation and realisation start with a description of a workflow procedure for creation of a coherent multi-disciplinary conceptual knowledge-based Holocene-prehistoric inventory of worldwide volcanological features groups, followed by the component implementation and realisation based on the general coherent multi-disciplinary conceptual knowledge implementation.

A. *Methodological workflow procedure*

A workflow procedure for the creation closely integrates the component framework and the coherent knowledge implementation of the Knowledge Resources (KR):

- (KR/components selection, continuous development.)
- Component implementation and realisation.
  - Scientific parametrisation of components (including algorithms, in each discipline).
  - Workflow decision making.
  - Country identification algorithm.
  - Country representation algorithm.
  - Area of Interest (AoI) representation algorithm.
  - Symbolic representation of country
  - Symbolic representation of AoI.
  - Knowledge and discipline depending algorithm creation.
  - Knowledge Resources processing.
  - Chorological assignment and processing, e.g., spatial calculations, e.g., countries and areas.
  - Chronological assignment and processing, e.g., time related calculations, e.g., geological and prehistoric.
- Coherent conceptual knowledge implementation.
  - Coherent conceptual knowledge references, main tables.
  - Coherent conceptual knowledge references, auxiliary tables.
- Symbolic representation, generation.
  - Context area views.
  - Symbolic representation of features groups, integrated visualisation.
  - (Further symbolic representation of narratives.)
  - (Multitude of further contextualisation and narratives.)
  - ...

After understanding the selected task-related algorithms and the fundamentals of knowledge complements many different realisations can be done straightforward, deploying the CKRI and CRI framework components.

The symbolic representation of features groups and the integrated visualisation will provide manifold ways of contextualisation. We can only demonstrate a single group of examples here.

Nevertheless, the realisation of the implemented workflow procedure may depend on the capacities the participating disciplines want to invest in their education, scientific research and contextualisation. It should not be uncommon with today's scientific research to invest increasing resources, 25 to over 50 percent of overall project resources, of each participating discipline into multi-disciplinary knowledge integration and contextualisation.

The CKRI and CRI framework can create coherent multi-disciplinary conceptual knowledge references effectively and efficiently and focus on core tasks within available capacities of time and other resources available for a workflow procedure.

B. *Component implementation and realisation*

The following passages give a compact overview of the major component framework integrated with this research. All the components and references are given, which were employed for the implementation and realisation and which are in a continuous further development process towards even closer integration and standards. More detailed, comprehensive discussion and examples regarding fundaments are available with the references on knowledge representations, methodology, contextualisation, and conceptual knowledge.

a) Conceptual knowledge frameworks: 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 [11]. CKRI can be created by any disciplines and for multi-disciplinary scenarios and coherently integrated, e.g., in contextualisation for prehistorical and archaeological narratives.

b) Conceptual knowledge base: Conceptual knowledge base is The *Universal Decimal Classification (UDC)* [12], 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 [12] released by the UDC Consortium, Creative Commons license [13].

c) Integration of scientific reference frameworks: Relevant scientific practices, frameworks, and standards from disciplines and contexts are integrated with the Knowledge Resources, e.g., here details regarding volcanological features, chronologies, spatial information, and Volcanic Explosivity Index (VEI) [14], [15].

d) Formalisation: All integration components, for all disciplines, require an *explicit and continuous formalisation* [16] *process*. The formalisation includes computation model support, e.g., *parallelisation standards, OpenMP* [17], [18], Reg Exp patterns, e.g., *Perl Compatible Regular Expressions (PCRE)* [19], and common standard methods, algorithms, and frameworks.

e) Methodologies and workflows integration: 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) [20] deploying the Generic Mapping Tools (GMT) and integrated modules [21] for visualisation.

f) Prehistory Knowledge Resources: Prehistoric objects and contexts are taken from *The Prehistory and Archaeology Knowledge Archive (PAKA)*, in continuous development for more than three decades [22] and is released by DIMF for the previous working edition [23] and this work [24]. The KR support seamless coherent multi-disciplinary conceptual knowledge integration for workflow procedures.

g) Natural Sciences Knowledge Resources: 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 [15] and with a wide range of contexts [11], [12], [25]. The KR support seamless coherent multi-disciplinary conceptual knowledge integration for workflow procedures.

h) Inherent representation groups: 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) [26], [27], HR Digital Chart of the World (DCW) [28], and Global Self-consistent Hierarchical High-resolution Geography (GSHHG) [29]. 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 [30], 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, [31], [32]. SRTM15 Plus [26], [27] is continuously updated and improved.

i) Scientific context parametrisation: Scientific *context parametrisation of prehistoric targets* can use the overall insight from all disciplines, e.g., parametrising algorithms and creating palaeolandscapes. Parametrisation is supported for all contexts and can consider views of participated disciplines. For the new inventory, parametrisation ranges from contexts, methods, representation of heights, illumination, symbol design, symbolic consistency to data locality and parallelisation.

j) Structures and symbolic representation: Structure is an organisation of interrelated entities in a material or non-material object or system [25]. 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* [33] 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.

C. Resulting coherent conceptual knowledge implementation

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

Universally consistent conceptual knowledge of CKRI references, based on UDC code references, for demonstration, spanning the main tables [34] shown in Table I. Table II shows an excerpt of universally consistent conceptual knowledge of CKRI references, based on UDC code references, spanning auxiliary tables [35].

The tables contain major UDC code references required for the implementation and realisation of the methodological workflow procedure, especially for place (countries and AoI), time (Holocene), and disciplines (volcanology and prehistory).

D. Resulting symbolic representation of features groups facets

The procedural component framework implementation and realisation enable the creation of numerous contextualisations and symbolic representations for the coherent multi-disciplinary conceptual knowledge-based Holocene-prehistoric inventory of volcanological features groups.

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

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

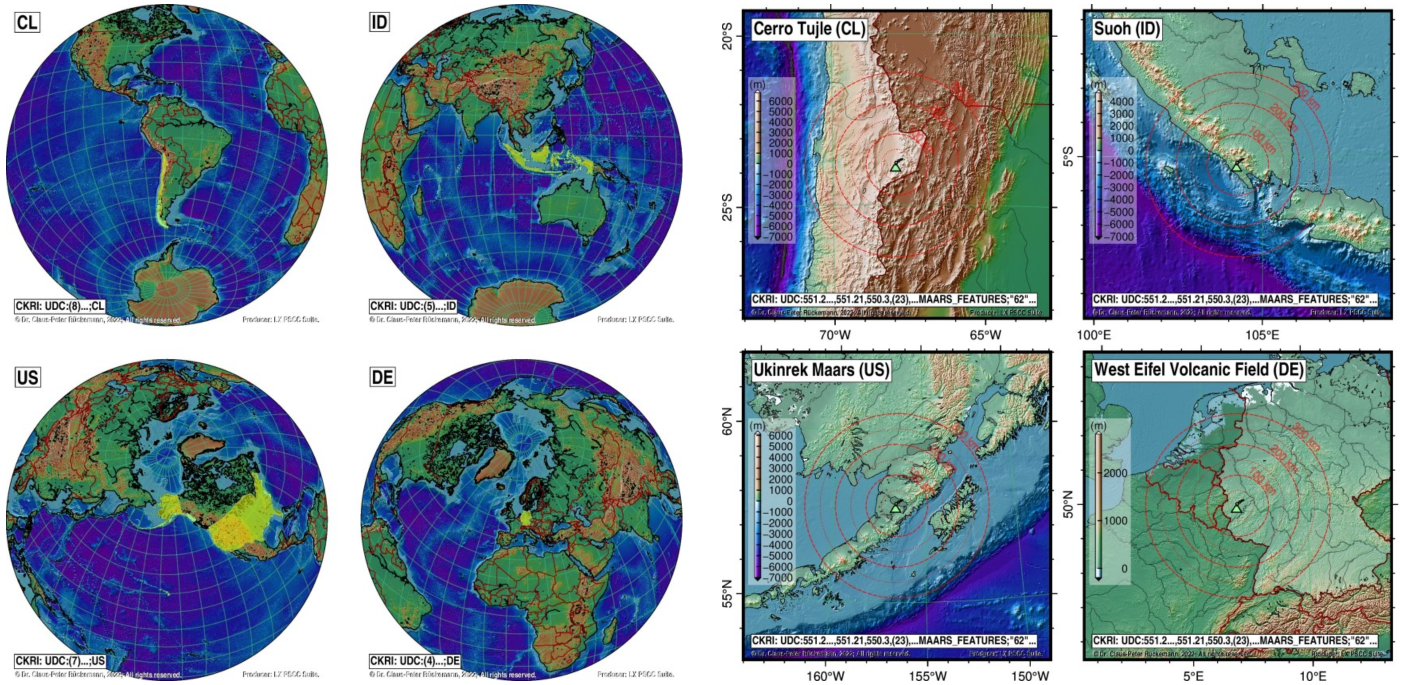
Code / Sign Ref.	*Verbal Description (EN)*
UDC (1/9)	Common auxiliaries of place
UDC:(23)	Above sea level. Surface relief. Above ground generally. Mountains
UDC:(3/9)	Individual places of the ancient and modern world
UDC:(3)	Places of the ancient and mediaeval world
UDC:(32)	Ancient Egypt
UDC:(35)	Medo-Persia
UDC:(36)	Regions of the so-called barbarians
UDC:(37)	Italia. Ancient Rome and Italy
UDC:(38)	Ancient Greece
UDC:(399)	Other regions. Ancient geographical divisions other than those of classical antiquity
UDC:(4/9)	Countries and places of the modern world
UDC:(4)	Europe
UDC:(5)	Asia
UDC:(6)	Africa
UDC:(7/8)	America, North and South. The Americas
UDC:(7)	North and Central America
UDC:(8)	South America
UDC:(9)	States and regions of the South Pacific and Australia. Arctic. Antarctic
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

For this research, we choose the resulting symbolic representation of a volcanological features group, maars, based on the coherent conceptual knowledge integration. Symbolic representation of contexts includes position based global projection of bathymetry / topography, automated country identification, multi-disciplinary context selection and reduction, chorological symbolic representation, geospherical projection considering national administrative boundaries. The symbolic representation of the global country identification exactly corresponds chorologically with that of the respective AoI context. Therefore all central positions of the representation are targeted to be precisely those of the volcanological object entities here.

The sequence of procedural steps enables contextualisation for flexible larger and smaller context scales, e.g., generated symbolic representation (Figure 1) of country identification contexts (Figure 1(a)) and generated symbolic representation of AoI contexts for respective object entities (Figure 1(b)). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas, based on the coherent conceptual knowledge.

The requested volcanological features groups facets created from the result matrix comprise the following objects with the status of this publication. The names are given along with the country code. The results of requested volcanological features groups facets and country identification contexts are given, along with the generated symbolic representation of AoI contexts for respective object entities. Context example references target Prehistoric Volcanic Activity (PVA) [3] for all volcanological features groups here, for the Holocene-prehistoric inventory. Due to the multi-disciplinary complexity and amount of contributions, complementary results and details from the research groups on multi-disciplinary conceptual knowledge have to be given in a separate publication [3].

- *Maars features:* Cerro Tujle (CL), Suoh (ID), Ukinrek Maars (US), West Eifel Volcanic Field (DE); (Figure 1: Country identification contexts, Figure 1(a); generated symbolic representation of AoI contexts for respective object entities, Figure 1(b)).
- *Strato volcano:* Agua de Pau (PT), Alngey (RU), Azuma (JP), Hekla (IS); (Figure 2: Country identification contexts, Figure 2(a); generated symbolic representation of AoI contexts for respective object entities, Figure 2(b)).
- *Shield volcano:* Volcán Darwin (EC), Kilauea (US), Santorini (GR), Waesche (AQ); (Figure 3: Country identification contexts, Figure 3(a); generated symbolic representation of AoI contexts for respective object entities, Figure 3(b)).
- *Explosion crater:* Bunyaruguru Field (UG), Dallol (ET), Koranga (PG), San Luis Gonzaga, Isla (MX); (Figure 4: Country identification contexts, Figure 4(a); generated symbolic representation of AoI contexts for respective object entities, Figure 4(b)).
- *Volcanic field:* Four Craters Lava Field (US), Gallego (SB), Volcán de San Antonio (ES), Volcán de Flores (GT); (Figure 5: Country identification contexts, Figure 5(a); generated symbolic representation of AoI contexts for respective object entities, Figure 5(b)).
- *Subglacial volcano:* Hoodoo Mountain (CA), Katla (IS), Loki-Fögrufjöll (IS), Volcan Viedma (AR); (Figure 6: Country identification contexts, Figure 6(a); generated symbolic representation of AoI contexts for respective



(a) Generated symbolic representation of country identification contexts.

(b) Generated symbolic representation of object AoI contexts.

Figure 1. Resulting symbolic representation of a volcanological features group facet (maars) based on coherent conceptual knowledge integration (excerpt). Sequence of procedural steps for larger scale and smaller scale contextualisation, including country identification contexts (a) and AoI contexts (b). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.

object entities, Figure 6(b)).

- *Submarine volcano:* Campi Flegrei Mar Sicilia (IT), Curacoa (TO), Shin-Iwo-Jima (JP), Vestmannaeyjar (IS); (Figure 7: Country identification contexts, Figure 7(a); generated symbolic representation of AoI contexts for respective object entities, Figure 7(b)).
- *Cones:* Bus-Obo (MN), Kabargin Oth Group (GE), Tore (PG), Tutuila (AS); (Figure 8: Country identification contexts, Figure 8(a); generated symbolic representation of AoI contexts for respective object entities, Figure 8(b)).
- *Complex volcano:* Marapi (ID), Soretimeat (VU), Unzen (JP), Vesuvius (IT). (Figure 9: Country identification contexts, Figure 9(a); generated symbolic representation of AoI contexts for respective object entities, Figure 9(b)).

In addition to these inventory groups facets, the high-resolution resources from different disciplines like prehistorical and classical archaeology, natural sciences, and humanities, all contributing to the component implementations and realisations enable to create consistent and coherent contextualisation for large scale scenarios up to site survey scales, e.g., for detailed object level diagrams and / or for a few kilometres of spatial extend.

IV. Discussion of procedural potential

Logic is a general limit to many overblown claims, from universal parallelisation to 'Artificial Instruments'.

Therefore, parallelisation can only deliver feasible approaches for simple, formalised cases of contextualisation and small parts of much more complex contexts of knowledge. The goals and complexity of conceptual knowledge-centric tasks and procedural tasks require the insight of eminently suitable structures and resources.

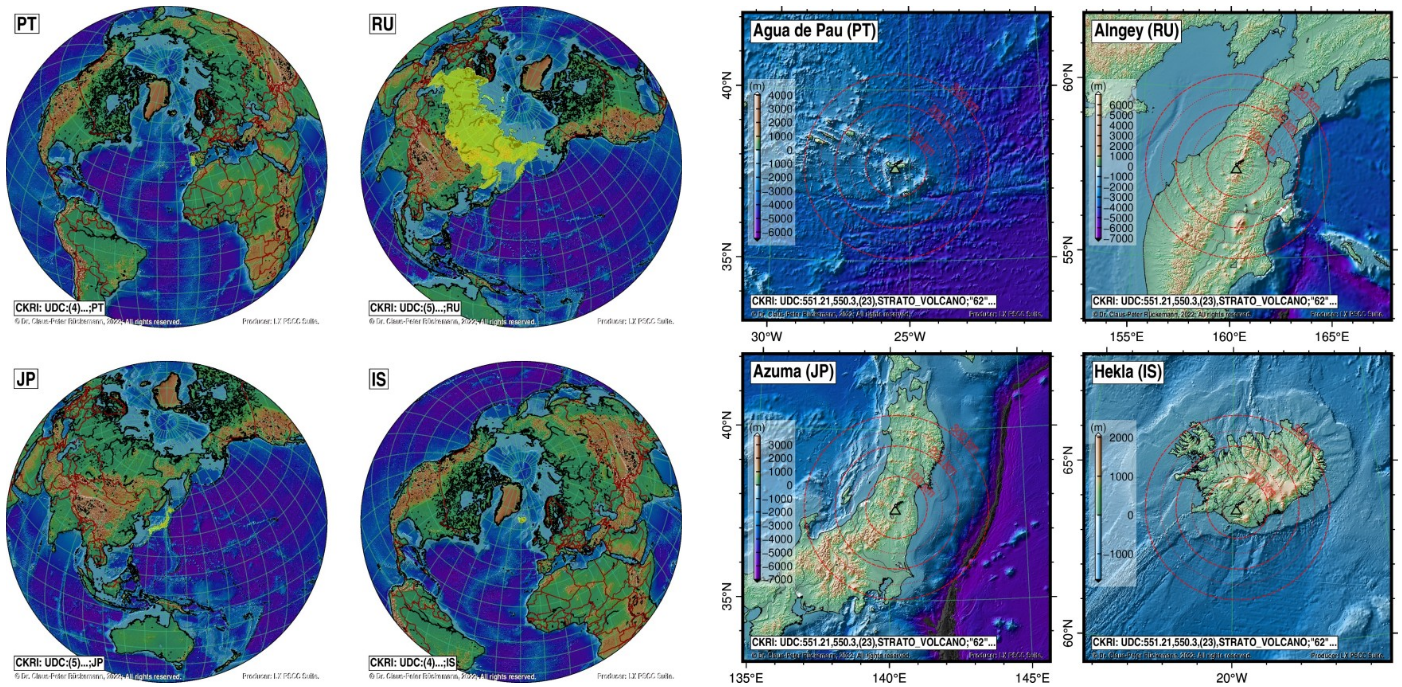
The resources, which provide highest potential for the realisation based on the inventory model are huge, based on quantity and resulting from quality of the contextualisation resources. Models are even continuously growing when considering ongoing state-of-the-art research. In consequence, these scenarios require a high level of scalability. A realistic conceptual-procedural environment for the coherent multi-disciplinary conceptual knowledge-based Holocene-prehistoric inventory of volcanological features groups includes:

- Different object groups, objects and views, e.g., for over 500 volcanological object entities and features.
- Multi-dimensional views, e.g., focus dependent views per objects, e.g., via OpenMP [17] / specifications [18].
- Embarrassingly parallel procedures (e.g., knowledge dimensional computation), e.g., via OpenMP [17] and specifications [18].
- Job parallel procedures (e.g., knowledge objects and resources localities).

Parallelisation does not solve knowledge related challenges of discipline inherent complexity but it can help to cope with implementation challenges of procedural and computational matters.

Table III shows the inherent representation groups used by the disciplines for the formalised representation of knowledge integrated for the implementation and realisation (serial, parallel, not applicable, n.a.).

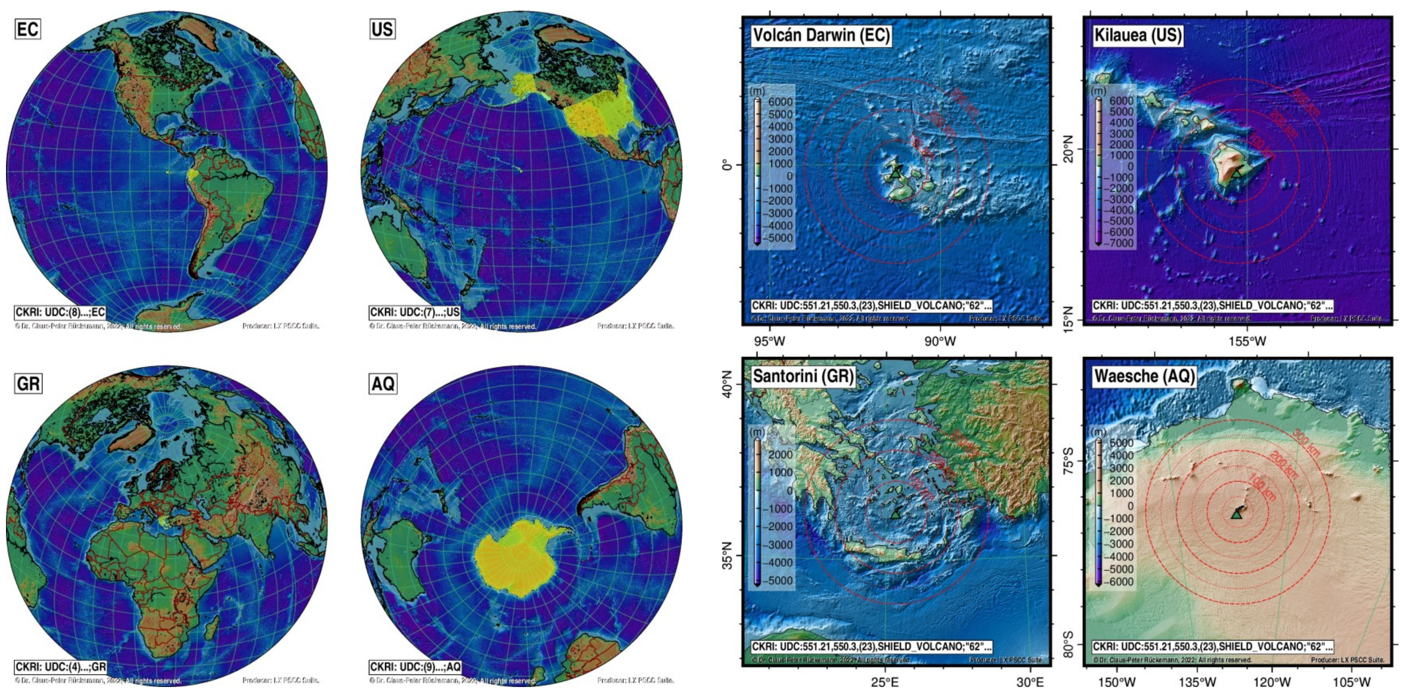
The respective locality-license and parallelisation aspects refer to the realisation resources, primarily depending on the respective knowledge and organisation. Therefore, precondition



(a) Generated symbolic representation of country identification contexts.

(b) Generated symbolic representation of object AoI contexts.

Figure 2. Resulting symbolic representation of a volcanological features group facet (stratovolcano) based on coherent conceptual knowledge integration (excerpt). Sequence of procedural steps for larger scale and smaller scale contextualisation, including country identification contexts (a) and AoI contexts (b). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.



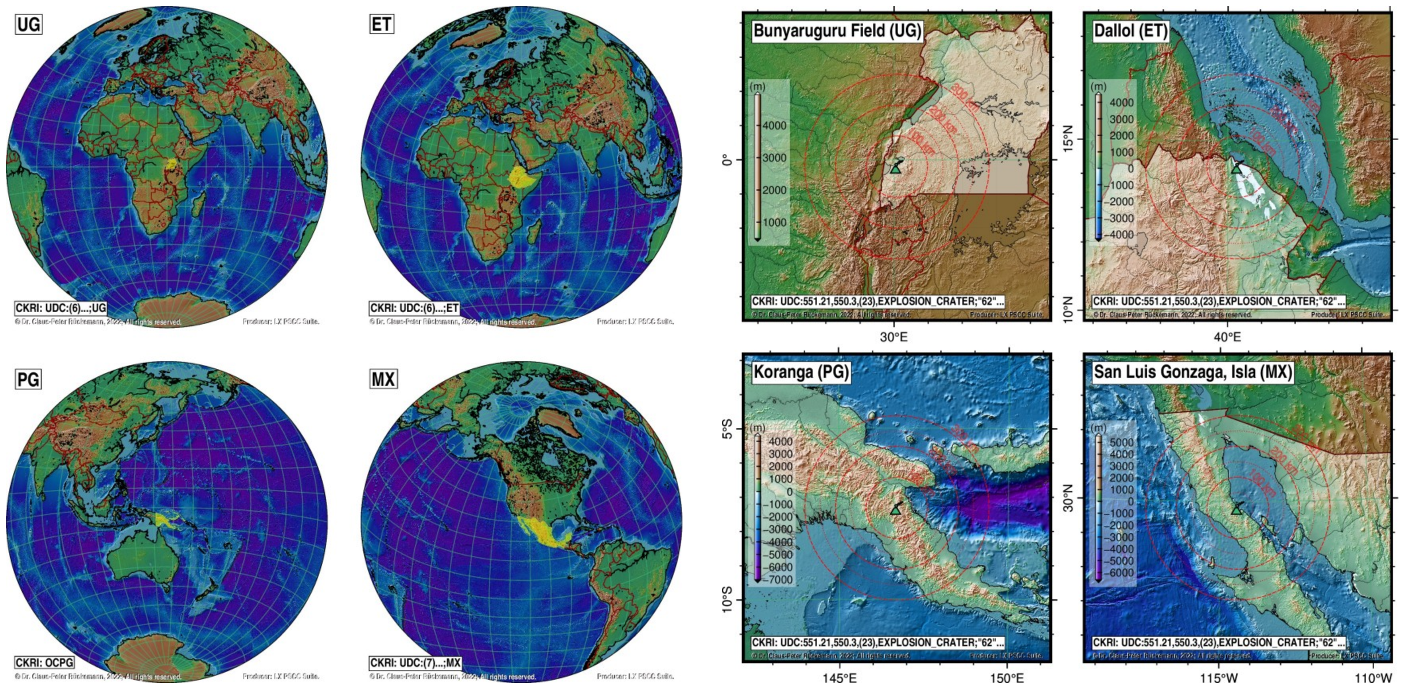
(a) Generated symbolic representation of country identification contexts.

(b) Generated symbolic representation of object AoI contexts.

Figure 3. Resulting symbolic representation of a volcanological features group facet (shield volcano) based on coherent conceptual knowledge integration (excerpt). Sequence of procedural steps for larger scale and smaller scale contextualisation, including country identification contexts (a) and AoI contexts (b). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.

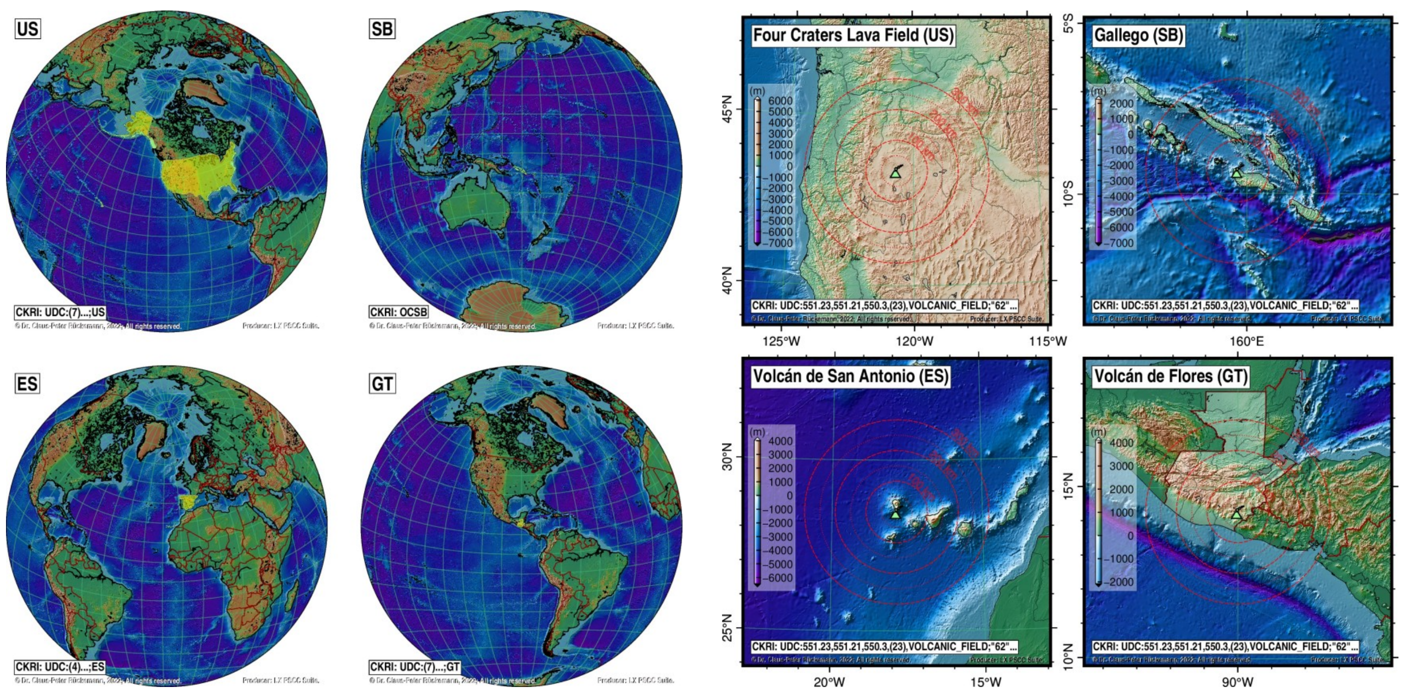
for implementation is a deep understanding of the knowledge complexity within a discipline, which is represented by the task as well as the required formalisations for all the components.

OpenMP is a mature and portable industry standard, which can be efficiently implemented directly by scientists of any discipline in their contextualisation, methodological workflow



(a) Generated symbolic representation of country identification contexts. (b) Generated symbolic representation of object AoI contexts.

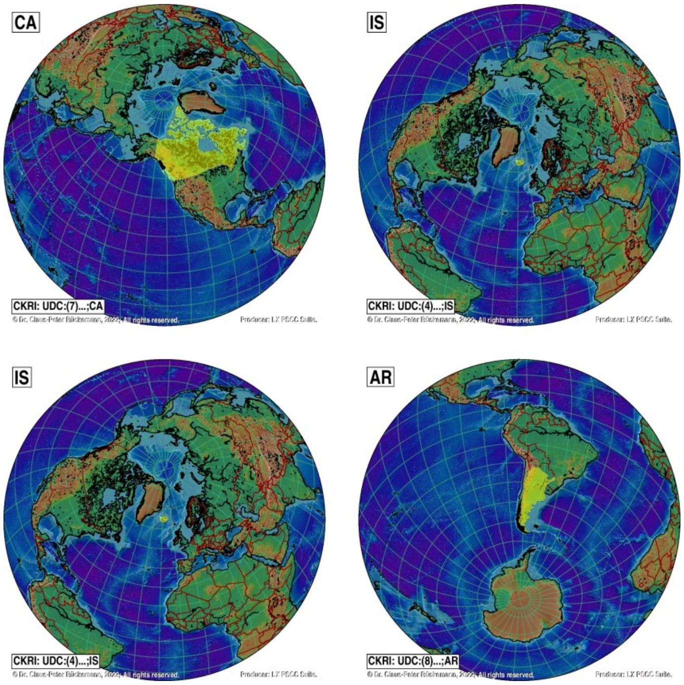
Figure 4. Resulting symbolic representation of a volcanological features group facet (explosion crater) based on coherent conceptual knowledge integration (excerpt). Sequence of procedural steps for larger scale and smaller scale contextualisation, including country identification contexts (a) and AoI contexts (b). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.



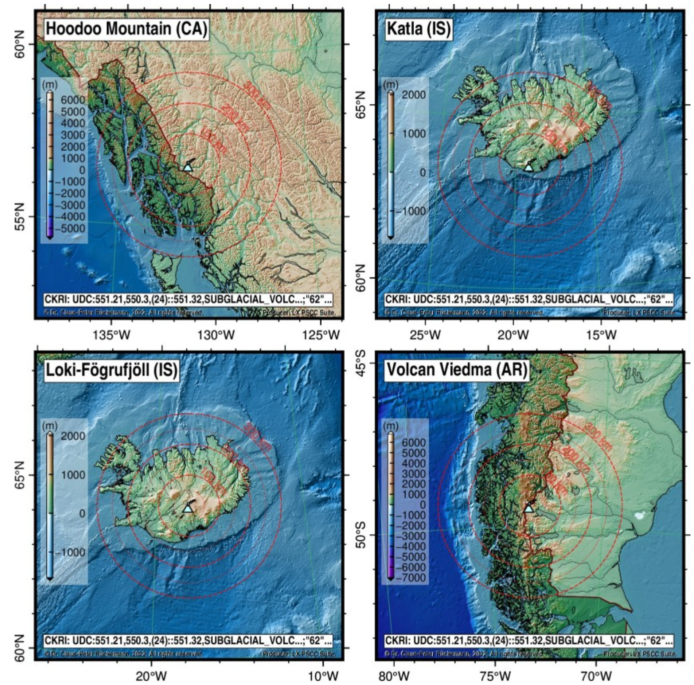
(a) Generated symbolic representation of country identification contexts. (b) Generated symbolic representation of object AoI contexts.

Figure 5. Resulting symbolic representation of a volcanological features group facet (volcanic field) based on coherent conceptual knowledge integration (excerpt). Sequence of procedural steps for larger scale and smaller scale contextualisation, including country identification contexts (a) and AoI contexts (b). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.

logic, and for their workflow procedure implementations and realisations. Organisation of data structure and formalisation of knowledge are core tasks of a discipline itself and not at all a technical task. Nevertheless, the organisation of knowledge also defines feasible data locality concepts. Parallelisation of workflows with plain-dimension and multi-dimension targets

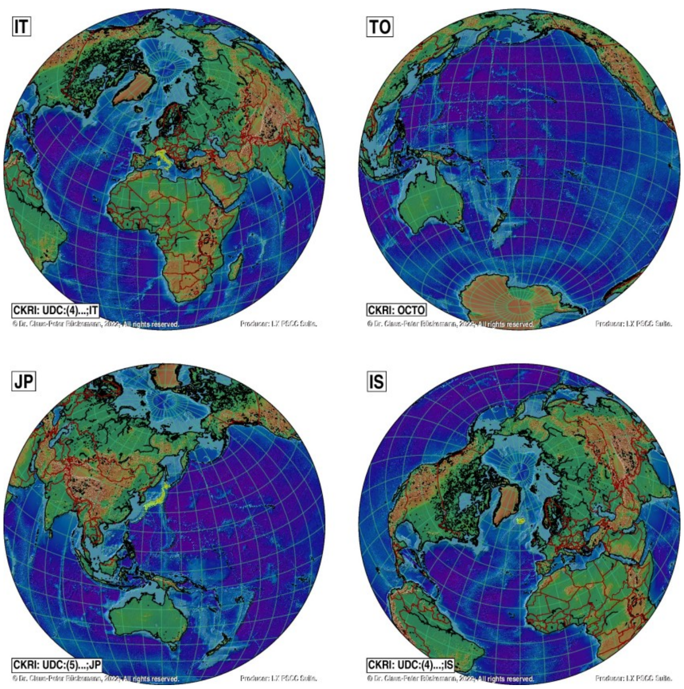


(a) Generated symbolic representation of country identification contexts.

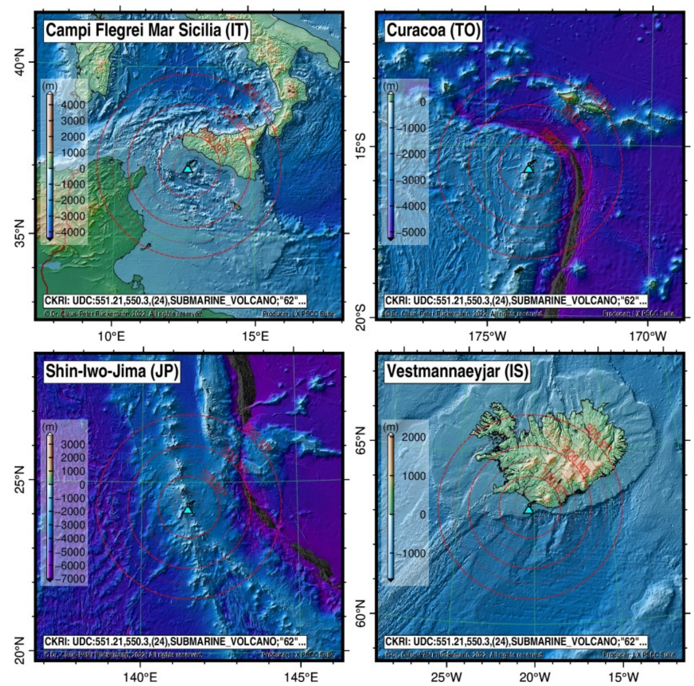


(b) Generated symbolic representation of object AoI contexts.

Figure 6. Resulting symbolic representation of a volcanological features group facet (subglacial volcano) based on coherent conceptual knowledge integration (excerpt). Sequence of procedural steps for larger scale and smaller scale contextualisation, including country identification contexts (a) and AoI contexts (b). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.



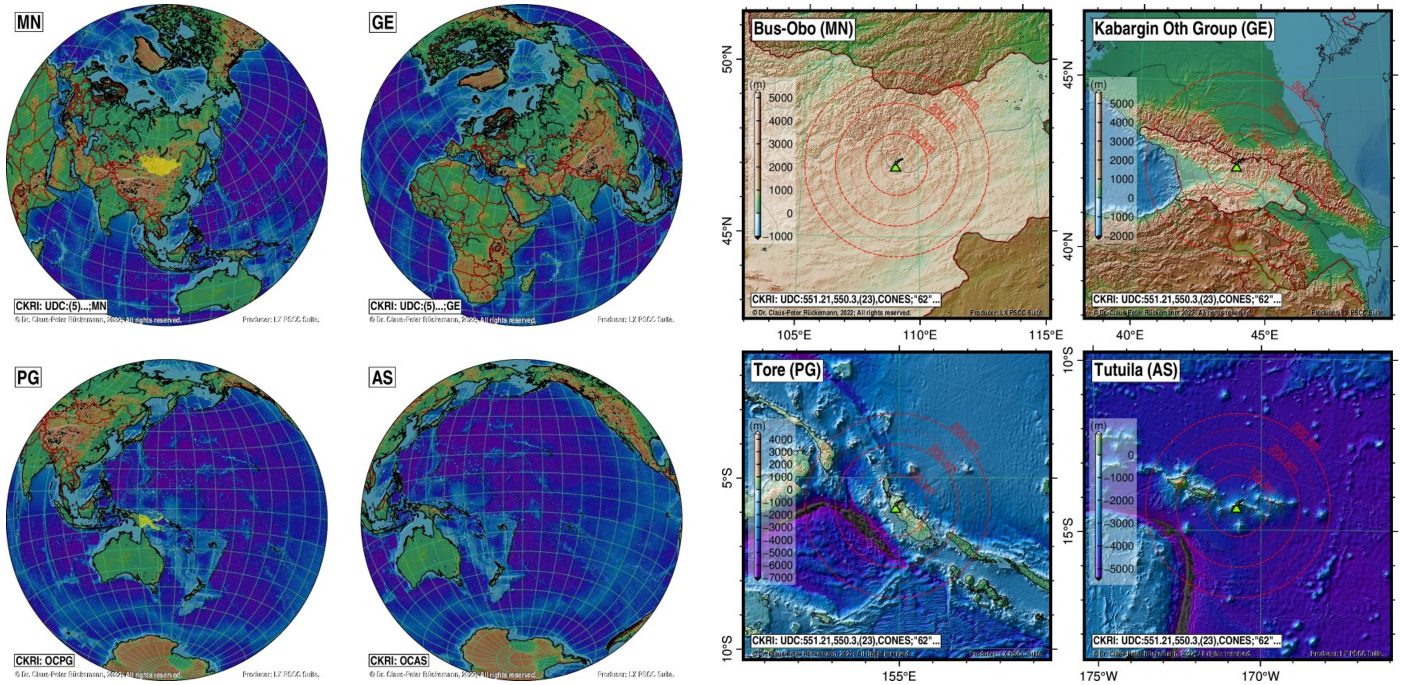
(a) Generated symbolic representation of country identification contexts.



(b) Generated symbolic representation of object AoI contexts.

Figure 7. Resulting symbolic representation of a volcanological features group facet (submarine volcano) based on coherent conceptual knowledge integration (excerpt). Sequence of procedural steps for larger scale and smaller scale contextualisation, including country identification contexts (a) and AoI contexts (b). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.

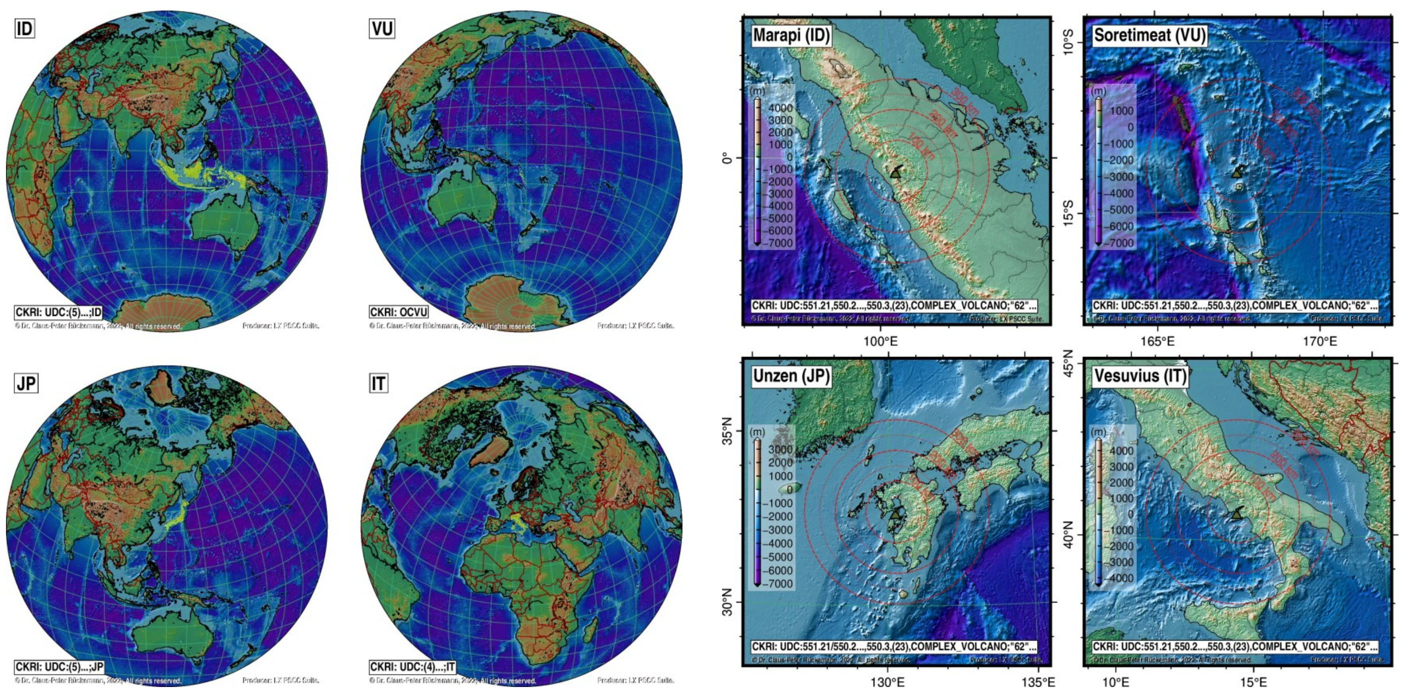
can differ regarding their contextualisation results. For example, a plain-dimension workflow can deliver different contextualisation contexts of an AoI. A multi-dimension workflow can deliver a certain contextualisation context of an AoI, depending on further dimensions, views or chorologies. Therefore, plain- and multi-dimension workflows can complement in



(a) Generated symbolic representation of country identification contexts.

(b) Generated symbolic representation of object AoI contexts.

Figure 8. Resulting symbolic representation of a volcanological features group facet (cone volcano) based on coherent conceptual knowledge integration (excerpt). Sequence of procedural steps for larger scale and smaller scale contextualisation, including country identification contexts (a) and AoI contexts (b). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.



(a) Generated symbolic representation of country identification contexts.

(b) Generated symbolic representation of object AoI contexts.

Figure 9. Resulting symbolic representation of a volcanological features group facet (complex volcano) based on coherent conceptual knowledge integration (excerpt). Sequence of procedural steps for larger scale and smaller scale contextualisation, including country identification contexts (a) and AoI contexts (b). Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas.

chorological and chronological contextualisation while sharing resources, structural and procedural fundaments. Most of the faceting is dealt with in the conceptual processing steps of the workflow. An example for a model reduction in plain-dimension is, e.g., generation of multiple context views. An example for a model reduction in multi-dimension is, e.g.,

TABLE III. INHERENT REPRESENTATION GROUPS WITH INTEGRATED COMPONENTS INVENTORY OBJECT ENTITY EXAMPLE WORKFLOW.

Inherent Representation Group	*Locality-License Model*	*Parallelisation Plain*	*Parallelisation Multi*
KR preprocessing, conceptual	On-premise	Ser. / par.	Ser. / par.
Context preprocessing	Restricted	Ser. / par.	Ser. / par.
KR processing, conceptual	On-premise	OpenMP	OpenMP
Conceptual knowledge processing	On-premise	OpenMP	OpenMP
PoI	On-premise	OpenMP	OpenMP
Point spatial operations	Restricted	OpenMP	OpenMP
Line operations	Restricted	OpenMP	OpenMP
Polygon operations	Restricted	OpenMP	OpenMP
DEM	Restricted	OpenMP	OpenMP
PCRE	Restricted	OpenMP	OpenMP
Editing	Restricted	OpenMP	OpenMP
Projecting	Restricted	OpenMP	OpenMP
Cutting	Restricted	OpenMP	OpenMP
Sampling	Restricted	OpenMP	OpenMP
Filtering	Restricted	OpenMP	OpenMP
Illumination	Restricted	OpenMP	OpenMP
Triangulation	Restricted	OpenMP	OpenMP
Projection	Restricted	OpenMP	OpenMP
Filter operations	On-premise	OpenMP	OpenMP
View/frame computation	Restricted	OpenMP	OpenMP
Model reduction (frames)	n.a.	OpenMP	OpenMP
Model reduction (animation)	n.a.	n.a.	Serial
...	...	...	...

generation of a video of geospherical satellite view frames with moving observer position. It is obvious that the workflow logic of the examples also differ in their ways of parallelisation. The use of on-premise (e.g., in-house) and restricted (distributed) resources is attributable to the licenses of the core assets, the knowledge resources. Inherent representation groups are major matter of scalable processing and conversion (two-dimensional/three-dimensional) and higher multi-dimensional workflow procedures.

Table IV shows the scalability of the example workflow procedure for parallelised parts of the coherent multi-disciplinary conceptual knowledge-based Holocene-prehistoric inventory of volcanological features groups, based on mean requirements for an object entity, with numbers of objects entities, n_o, numbers of frames, n_f, and numbers of views, n_v, for $n_f = 1$ and $n_v = 2$ as in the above symbolic representation example of volcanological features groups.

TABLE IV. PARALLELISED PROCESSING OF INVENTORY WORKFLOW (PARALLELISED KNOWLEDGE RESOURCES AND CONTEXT RESOURCES).

Number of CPU Cores	*Wall Time Workflow (Plain)*	*Number of Object Entities* $n_o = 100$	$n_o = 500$
1	$n_o \cdot (n_v \cdot n_f \cdot 1,680/1)$ s	336,000 s	1,680,000 s
36	$n_o \cdot (n_v \cdot n_f \cdot 1,680/36)$ s	9,333 s	46,667 s

The architecture choosen for this realisation is an efficient 36-core-based Central Processing Unit (CPU) (Intel Xeon), which is taking into account that we commonly use 36 cores for many basic global approaches, e.g., considering the 360 degrees of a global model. Results on other architectures with same numbers of respective cores will be highly comparable.

Precondition for parallelisation is sufficient memory for parallel use of integrated resources. Considering the employed resources, e.g., SRTM, 128 GB for 36 parallel processes is comfortable when data limits are cut to the limits required for the algorithms with the range of a few hundred kilometres area per object entity.

Wall and compute times, especially of multi-dimensional workflow results, can greatly be reduced from the integrated parallelisation, which makes the procedural solution highly scalable. The wall times for numbers of objects entities, n_o, illustrate the high scalability when the same workflow is using higher numbers of CPU cores. Probably, most practical workflows may contain parts which cannot be reasonably parallelised. This is especially true for scientific tasks with a certain complexity. The percentage of non parallelised parts is very low here. For multi-dimension targets, e.g., animations with $n_f = 1000$ and $n_v = 1$, it may be considered to employ hundreds to thousands of CPU cores so parallelised wall times per object can be reduced from days to hours.

That means, for the scenario and inventory subset displayed in this publication all the symbolical representation, contextualisation, and visualisation can be continuously assembled and updated based on highest resolution satellite data and continuously updated Knowledge Resources on one processor in less than an hour now with the given compute resources. Anyhow, workflow time consumption may be non-linear, depending on the reflected scenario and present status of integrated resources.

Serial and parallel compute times, e.g., for groups of object entities, are non-linear. For example, mean times for the same workflow realisation may greatly differ for different object entities. To significant extent, this is consequence of the inherent complexity of the knowledge complements, which have to be integrated and analysed. In practice, compute times for object entities may commonly vary to over several hundred percent. Component and knowledge contributions of different disciplines may have different weight in their contributions to the non-linearities. The resulting compute times may even deliver continuously new and non-linear compute times in a dynamical workflow realisation with knowledge resources and components, which are in continuous development.

In principle two basic constellation categories exist here with multi-dimensional results, temporal static and positional static. Including faceting, both categories can be fully parallelised regarding view/frame computation, e.g., via OpenMP.

The compute requirements are about the same for both categories, mostly depending on the parametrisation of used resources and components, including faceting. Nevertheless, due to the characteristics and diversity of real scenarios and environments the compute requirements differ to some extend with the targeted chorology and chronology. Levels of effective parallelisation may differ due to amounts of data to be processed, e.g., satellite and model data. Compute intensities depend on the target object entity, too, not only on an object group facet.

In addition, processing, analysis, and conversion requirements may also largely depend on the number and complexity of vector objects in the respective object entity contexts. At least if preprocessing, e.g., resizing, scaling, and resampling, is not common to more than one target, e.g., a frame in one of either categories, that part of the processing should be done once in a sub-loop only and not in parallelisation.

For organisational reasons with discipline related knowledge development processes, every loop might require an individual preprocessing, which might not be possible to be parallelised or requires a decoupled parallelisation. These aspects, discipline related knowledge development and faceting, are addressing methodological principles and should be dealt with by members of the responsible discipline, e.g., from archaeology.

Anyhow, commonly this preprocessing is a minor computational effort of less then a few percent overall but essential for the contextualisation.

V. Conclusion

The new approaches for the creation of a sustainable procedural component framework for implementation and realisation of a coherent multi-disciplinary conceptual knowledge-based inventory and faceting proved efficient and sustainable. Based on the methodology of coherent conceptual knowledge classification, the CKRI, and the CRI frameworks, the procedural and conceptual implementation and realisation of a Holocene-prehistoric inventory of worldwide volcanological features groups facets showed very flexible and scalable, supported by many scenarios over the last years. The developed framework of components, can be employed for multi-disciplinary integration of knowledge contexts. Everything has been done to deploy standards and provide maximum flexibility so that context from prehistory, archaeology, natural sciences, and humanities can be be coherently integrated. The methodology of coherent conceptual knowledge contextualisation and its implemented methods proved to enable coherent context integration in prehistory and archaeology, sustainable, advanced contextualisation [36] and method integration [37], e.g., for prehistorical and classical archaeology and their multi-disciplinary contexts. The component framework showed to enable an effective and efficient coherent multi-disciplinary conceptual knowledge contextualisation and georeferenced symbolic representation and proved most scalable and sustainable during all long-term development and practical use.

Researchers from all disciplines already practice the procedural component framework development, coherent conceptual knowledge, and procedure parallelisation in professional long-term research knowledge and data management.

Together with the corresponding conceptual knowledge reference implementation, the CRI framework of components will on long-term be employed in a wide range of disciplines and different ongoing projects in prehistorical and classical archaeology and multi-disciplinary contextualisation.

The methodology enables the practical contextualisation and integration of knowledge, supporting systematical and methodological backprojections for disciplines employing their methods in interaction with future multi-dimensional and multi-disciplinary knowledge models and symbolic representations.

Future research will address the creation of a component framework for further developing the Holocene-prehistoric inventory of worldwide volcanological features, which enables coherent multi-disciplinary conceptual knowledge facets and procedural integration and coherent multi-disciplinary conceptual knowledge contextualisation with prehistorical and archaeological knowledge resources and new advanced multi-dimensional context integration models.

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