Faceting the 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 extended research and current status on a practical solution for geoscientific inventories based on conceptual contextualisation. The goal of this research is the creation and further development 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 multi-disciplinary conceptual knowledge contextualisation and georeferenced symbolic representation. This paper provides the status of conceptual knowledge facets, implementations and realisations of the coherent conceptual knowledge and the methodological component integration. The resulting inventory is illustrated by resulting excerpts of major volcanological features groups based on a conceptual knowledge result matrix. Future research will address the resulting Holocene-prehistoric inventory of worldwide volcanological feature groups, continuous development of resources and integration and coherent multi-disciplinary conceptual knowledge contextualisation with prehistorical and archaeological knowledge resources for creation of new insight.**

Keywords–Holocene-prehistoric Inventory of Volcanological Features Groups; Contextualisation; Coherent Multi-disciplinary Conceptual Knowledge Faceting and Integration; CKRI; CRI Framework.

I. INTRODUCTION

This paper is an extended and updated presentation of the research based on the publication and presentation at the GEOProcessing 2022 conference in Porto, Portugal [1]. Due to a number of recent requests for the created inventory, we take the chance that this extended paper can concentrate on the practical inventory, showing a wider range of result groups based on practical conceptual facets used for on-demand contextualisation and symbolic representation.

The corresponding procedural component framework implementation and realisation for creation of a multi-disciplinary coherent conceptual knowledge-based Holocene-prehistoric inventory of volcanological features groups is described in detail [2] along with the overall frame [3] and importance of information science methods and structures [4]. Faceting aspects employing procedural components is provided with an extended view on implementations [5].

The goal of this research is the creation and further development 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 [6], considering that many facets of knowledge, including prehistory, need to be continuously acquired and reviewed [7]. 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 Conceptual Knowledge Reference Implementation (CKRI) [8] and the Component Reference Implementations (CRI) framework [9]. The reference implementations were created with coherent conceptual knowledge and sustainable standardised components in mind.

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

II. MAJOR REFERENCE IMPLEMENTATIONS

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) [8] and the Component Reference Implementations (CRI) framework [9]. CKRI provides the knowledge framework, including multi-disciplinary contexts of natural sciences and humanities [10]. 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 [11], including meaning, can be described using knowledge complements supporting a modern definition of knowledge [12] and subsequent component instrumentation, e.g., considering factual, conceptual, procedural, metacognitive, and structural knowledge.

Especially, conceptual knowledge can relate to any of factual, conceptual, procedural, 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. All the components are in continuous development by the respective disciplines themselves.

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.

III. Methodological implementation and realisation

Implementation and realisation are based on the CKRI reference implementation [8], 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 [9]. Both provide sustainable fundaments for highest levels of reproducibility and standardisation.

A. Resulting coherent conceptual knowledge implementation

Universally consistent multi-disciplinary conceptual knowledge is based on the Conceptual Knowledge Reference Implementation (CKRI) [8] and implemented via UDC code references for demonstration, spanning the main tables [13] shown in Table I and major discipline knowledge, ‘natural sciences’ (Table II) and ‘history’ (Table III).

Table I. CKRI implementation of coherent conceptual knowledge contextualisation; main tables.

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:6	Applied Sciences. Medicine, Technology
UDC:7	The Arts. Entertainment. Sport
UDC:8	Linguistics. Literature
UDC:9	Geography. Biography. History

Table II. CKRI implementation of coherent conceptual knowledge contextualisation: ... natural sciences (excerpt).

Code / Sign Ref.	*Verbal Description (EN)*
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

Table III. CKRI implementation of coherent conceptual knowledge contextualisation: ... history (excerpt).

Code / Sign Ref.	*Verbal Description (EN)*
UDC:9	Geography. Biography. History
UDC:902	Archaeology
UDC:903	Prehistory. Prehistoric remains, artefacts, antiquities
UDC:904	Cultural remains of historical times

Table IV shows an excerpt of consistent multi-disciplinary conceptual knowledge based on UDC code references spanning auxiliary tables [14].

Table IV. 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 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.

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 [9]. The employed CRI framework corresponds with development stage edition E.0.3.9.

The ten major CRI component groups were integrated for the implementation and realisation of the practical Holocene-prehistoric inventory of volcanological features groups.

In summary, with this short excursus on procedural components here, the main component groups are focussing on:

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. All component groups are supporting conceptual knowledge and respective faceting.

Relevant pre-existing and ongoing component developments addressing knowledge with multi-disciplinary KR have been summarised [15]. 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.

IV. Resulting inventory and faceting

The following sections provide illustrative object entity examples of the new practical Holocene-prehistoric inventory of volcanological features groups facets as implemented and realised integrating the aforementioned reference implementations. Figure V shows an excerpt of respective features groups facets and their chronological and context references respective volcanic activities and contexts resulting from the resources.

Table V. Holocene-prehistoric Volcanological features group facets (excerpt), Holocene-prehistoric corresponding with Prehistoric Volcanic Activity.

Volcanological Features Group	*Volcanic Activity*	*Context Example*
Strato volcano	Holocene	PVA
Maars features	Holocene	PVA
Shield volcano	Holocene	PVA
Explosion crater	Holocene	PVA
Volcanic field	Holocene	PVA
Subglacial volcano	Holocene	PVA
Submarine volcano	Holocene	PVA
Cones	Holocene	PVA
Complex volcano	Holocene	PVA

Context example references for the Holocene-prehistoric Inventory of volcanological features groups are Prehistoric Volcanic Activity (PVA) for all volcanological features groups. These features groups facets provide a base for the conceptual knowledge facets. The context examples will be discussed in more detail the following, presenting the result matrix of facets and contexts.

A. *Resulting coherent conceptual knowledge facets integration*

The coherent conceptual knowledge integration enables facet creation and 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.

Table VI shows an excerpt of the result matrix of Holocene-prehistoric volcanological features groups and respective facets, namely conceptual knowledge, chronology, and chorology. The result matrix includes conceptual knowledge view groups [16] based on CKRI references [8], factual knowledge from the Knowledge Resources objects, and respective country codes.

Context example references for the features groups facets show Prehistoric Volcanic Activity (PVA), Historic Volcanic Activity (HVA), and Continued Volcanic Activity (CVA), e.g., latent volcanic activity. PVA are consequence of the Holocene-prehistoric target for all objects in the resulting volcanological features groups. Cases for which further facts are holding true can also allow past-prehistoric contextualisation, e.g., with HVA and CVA. Multi-disciplinary contextualisation further depends on the availability of respective factual knowledge, e.g., via The Prehistory and Archaeology Knowledge Archive (PAKA) [17]. Any case can be dynamically contextualised with multi-disciplinary knowledge, especially from prehistory and archaeology, e.g., referring to prehistoric object properties and excavation results and targeting new insight from geoscientific and multi-disciplinary context integration. The methodology enables to create methods as displayed in the following sections, supporting many features required for integration and analysis, e.g., semi-automated referencing, chorology faceting, chronology faceting, multi-disciplinary contexts, and creation of result matrices.

The result matrices and facets reflect the key assets with the CRI framework [9] to realise the inventory and symbolic representations and to enable a continuous development.

B. *Resulting symbolic representation of features groups facets*

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 bathymetric and topographic results, and further knowledge for respective areas. The symbolic representation enables the signification of the different facets. Here distinctly coloured volcano symbols represent the volcanological features groups and respective conceptual knowledge facets in the visualisation of the result matrix objects. Figure 2 shows a resulting symbolic representation of a volcanological features group, maars, as based on the coherent conceptual knowledge integration. The views of the result matrix further include the conceptual knowledge features groups facets of shield volcanoes (Figure 3), explosion craters (Figure 4), volcanic fields (Figure 5), subglacial volcanoes (Figure 6), submarine volcanoes (Figure 7), cones (Figure 8), and complex volcanoes (Figure 9).

The resulting symbolic representations reflect the coherent conceptual knowledge (CKRI, UDC references) and bathymetric and topographic knowledge (CRI components). Projection

TABLE VI. RESULT MATRIX OF HOLOCENE-PREHISTORIC VOLCANOLOGICAL FEATURES GROUPS FACETS (EXCERPT). IT INCLUDES CONCEPTUAL KNOWLEDGE VIEW GROUPS [16] (CKRI), VOLCANIC ACTIVITY, CONTEXTS, KNOWLEDGE RESOURCES OBJECTS, AND COUNTRY CODES (EXCERPT).

Multi-disciplinary Conceptual Knowledge Facets	*Chronology Facets*		*Chorology Facets*	
Volcanological Features Conceptual Knowledge View / Facets Group	*Volcanic Activity*	*Context*	*Knowledge Resources Object*	*Country Code*
CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;"62"...	Holocene	PVA / HVA	Agua de Pau	PT
CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;"62"...	Holocene	PVA	Alngey	RU
CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;"62"...	Holocene	PVA / HVA	Azuma	JP
CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;"62"...	Holocene	PVA / HVA	Hekla	IS
CKRI: UDC:551.21,550.3,(23),STRATO_VOLCANO;"62"...	Holocene	PVA	...	...
CKRI: UDC:551.2...,551.21,550.3,(23),...MAARS_FEATURES;"62"...	Holocene	PVA	Cerro Tujle	CL
CKRI: UDC:551.2...,551.21,550.3,(23),...MAARS_FEATURES;"62"...	Holocene	PVA / HVA	Suoh	ID
CKRI: UDC:551.2...,551.21,550.3,(23),...MAARS_FEATURES;"62"...	Holocene	PVA / HVA	Ukinrek Maars	US
CKRI: UDC:551.2...,551.21,550.3,(23),...MAARS_FEATURES;"62"...	Holocene	PVA / (CVA)	West Eifel Volcanic Field	DE
CKRI: UDC:551.2...,551.21,550.3,(23),...MAARS_FEATURES;"62"...	Holocene	PVA	...	...
CKRI: UDC:551.21,550.3,(23),SHIELD_VOLCANO;"62"...	Holocene	PVA / (CVA)	Volcán Darwin	EC
CKRI: UDC:551.21,550.3,(23),SHIELD_VOLCANO;"62"...	Holocene	PVA / HVA	Kilauea	US
CKRI: UDC:551.21,550.3,(23),SHIELD_VOLCANO;"62"...	Holocene	PVA / HVA	Santorini	GR
CKRI: UDC:551.21,550.3,(23),SHIELD_VOLCANO;"62"...	Holocene	PVA	Waesche	AQ
CKRI: UDC:551.21,550.3,(23),SHIELD_VOLCANO;"62"...	Holocene	PVA	...	...
CKRI: UDC:551.21,550.3,(23),EXPLOSION_CRATER;"62"...	Holocene	PVA / (CVA)	Bunyaruguru Field	UG
CKRI: UDC:551.21,550.3,(23),EXPLOSION_CRATER;"62"...	Holocene	PVA / HVA	Dallol	ET
CKRI: UDC:551.21,550.3,(23),EXPLOSION_CRATER;"62"...	Holocene	PVA	Koranga	PG
CKRI: UDC:551.21,550.3,(23),EXPLOSION_CRATER;"62"...	Holocene	PVA	San Luis Gonzaga, Isla	MX
CKRI: UDC:551.21,550.3,(23),EXPLOSION_CRATER;"62"...	Holocene	PVA	...	...
CKRI: UDC:551.23,551.21,550.3,(23),VOLCANIC_FIELD;"62"...	Holocene	PVA	Four Craters Lava Field	US
CKRI: UDC:551.23,551.21,550.3,(23),VOLCANIC_FIELD;"62"...	Holocene	PVA	Gallego	SB
CKRI: UDC:551.23,551.21,550.3,(23),VOLCANIC_FIELD;"62"...	Holocene	PVA / HVA	Volcán de San Antonio	ES
CKRI: UDC:551.23,551.21,550.3,(23),VOLCANIC_FIELD;"62"...	Holocene	PVA	Volcán de Flores	GT
CKRI: UDC:551.23,551.21,550.3,(23),VOLCANIC_FIELD;"62"...	Holocene	PVA	...	...
CKRI: UDC:551.21,550.3,(24)::551.32,SUBGLACIAL_VOLC...;"62"...	Holocene	PVA	Hoodoo Mountain	CA
CKRI: UDC:551.21,550.3,(24)::551.32,SUBGLACIAL_VOLC...;"62"...	Holocene	PVA / HVA	Katla	IS
CKRI: UDC:551.21,550.3,(24)::551.32,SUBGLACIAL_VOLC...;"62"...	Holocene	PVA / HVA	Loki-Fögrufjöll	IS
CKRI: UDC:551.21,550.3,(24)::551.32,SUBGLACIAL_VOLC...;"62"...	Holocene	PVA / HVA	Volcan Viedma	AR
CKRI: UDC:551.21,550.3,(24)::551.32,SUBGLACIAL_VOLC...;"62"...	Holocene	PVA	...	...
CKRI: UDC:551.21,550.3,(24),SUBMARINE_VOLCANO;"62"...	Holocene	PVA / HVA	Campi Flegrei Mar Sicilia	IT
CKRI: UDC:551.21,550.3,(24),SUBMARINE_VOLCANO;"62"...	Holocene	PVA / HVA	Curacoa	TO
CKRI: UDC:551.21,550.3,(24),SUBMARINE_VOLCANO;"62"...	Holocene	PVA / HVA	Shin-Iwo-Jima	JP
CKRI: UDC:551.21,550.3,(24),SUBMARINE_VOLCANO;"62"...	Holocene	PVA / HVA	Vestmannaeyjar	IS
CKRI: UDC:551.21,550.3,(24),SUBMARINE_VOLCANO;"62"...	Holocene	PVA	...	...
CKRI: UDC:551.21,550.3,(23),CONES;"62"...	Holocene	PVA	Bus-Obo	MN
CKRI: UDC:551.21,550.3,(23),CONES;"62"...	Holocene	PVA	Kabargin Oth Group	GE
CKRI: UDC:551.21,550.3,(23),CONES;"62"...	Holocene	PVA	Tore	PG
CKRI: UDC:551.21,550.3,(23),CONES;"62"...	Holocene	PVA	Tutuila	AS
CKRI: UDC:551.21,550.3,(23),CONES;"62"...	Holocene	PVA	...	...
CKRI: UDC:551.21,550.2...,550.3,(23),COMPLEX_VOLCANO;"62"...	Holocene	PVA / HVA	Marapi	ID
CKRI: UDC:551.21,550.2...,550.3,(23),COMPLEX_VOLCANO;"62"...	Holocene	PVA / HVA	Soretimeat	VU
CKRI: UDC:551.21/550.2...,550.3,(23),COMPLEX_VOLCANO;"62"...	Holocene	PVA / HVA	Unzen	JP
CKRI: UDC:551.21,550.2...,550.3,(23),COMPLEX_VOLCANO;"62"...	Holocene	PVA / HVA	Vesuvius	IT
CKRI: UDC:551.21,550.2...,550.3,(23),COMPLEX_VOLCANO;"62"...	Holocene	PVA	...	...
...	...	...	...	...

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 and facets.

These features groups integrate bathymetric and topographic knowledge, for example. Here, available multi-disciplinary knowledge can be used for contextualisation, e.g., representing characteristics, physical properties, plate tectonics, soil, and age. Further features allow analysis of contexts, e.g., prehistorical and archaeological properties, continentality regime, coast line dependences, and coast distance. The conceptual knowledge view groups of object entities of Holocene-prehistoric volcanological features groups correspond with the result matrix (Table VI).

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 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.

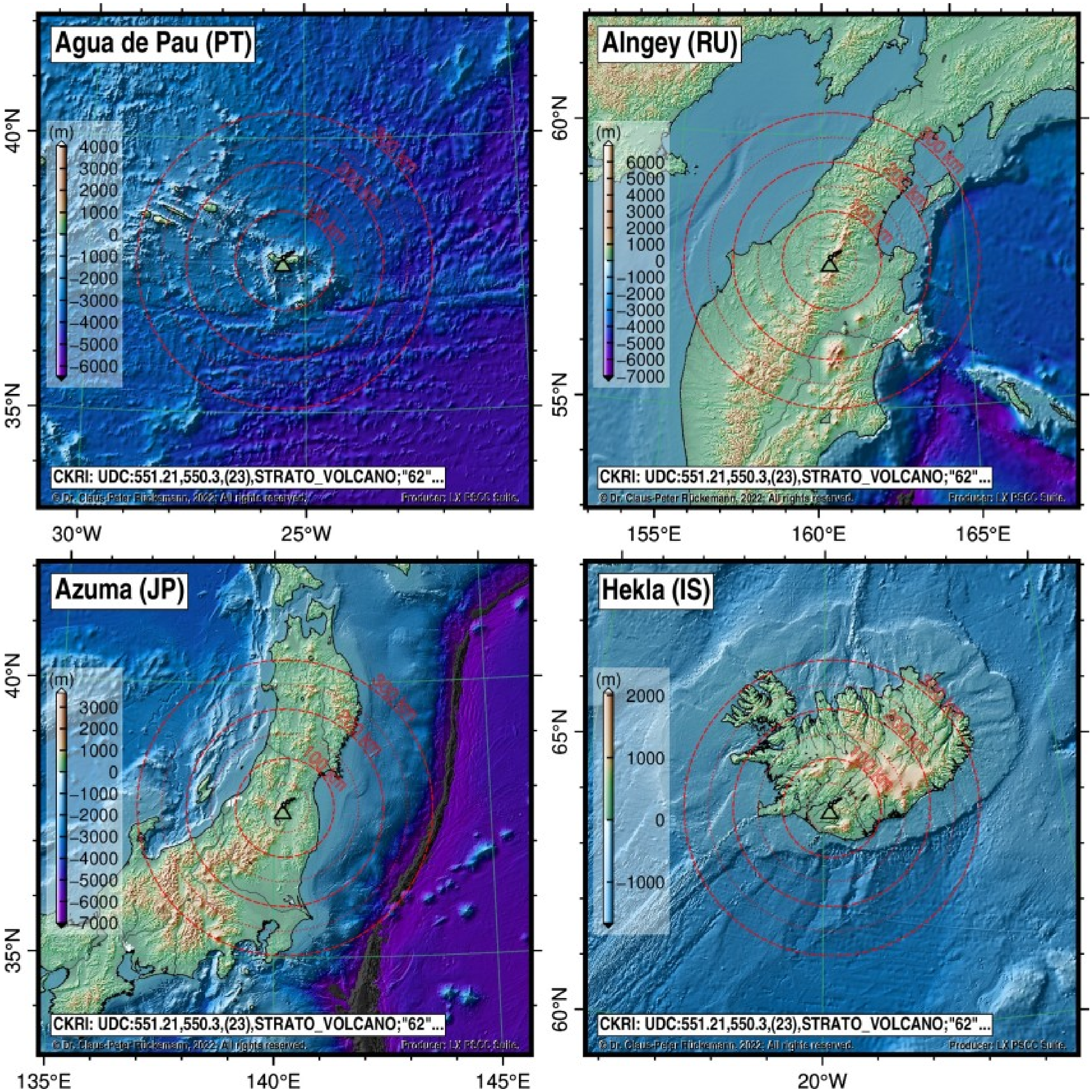

Figure 1. Resulting symbolic representation of a volcanological features group facet (strato volcano) based on coherent conceptual knowledge integration (excerpt). Generated results include CKRI references, projection of bathymetric / topographic results, and further knowledge for respective areas.

V. 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 IV) are used with the implementation and realisation *KR* [15].

Conceptual knowledge base is The *Universal Decimal Classification (UDC)* [16], 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 [16] released by the UDC Consortium, Creative Commons license [18].

Relevant scientific practices, frameworks, and standards from disciplines and contexts are integrated with the Knowledge Resources, e.g., here details regarding volcanological

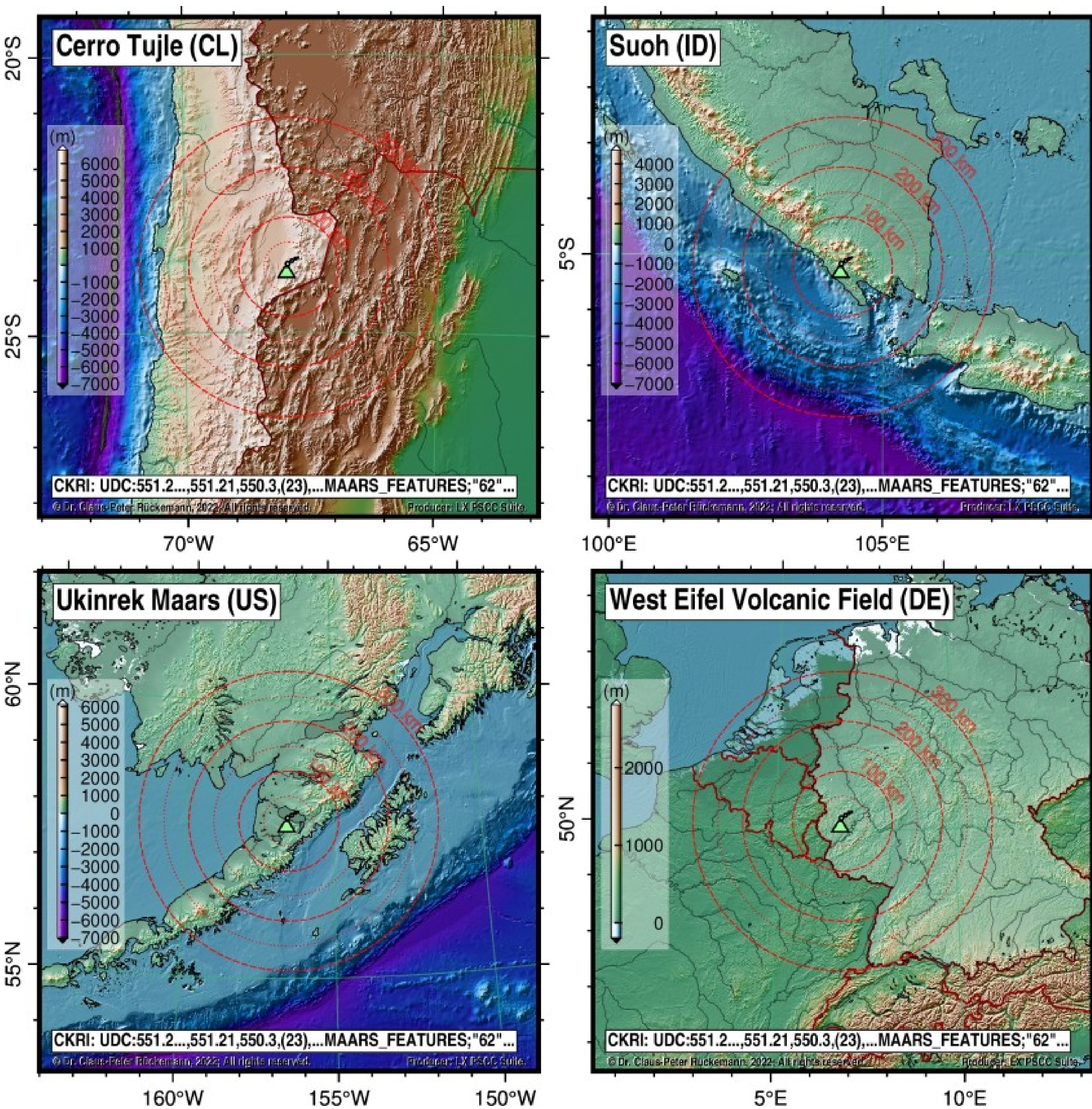

Figure 2. Resulting symbolic representation of a volcanological features group facet (maars) based on coherent conceptual knowledge integration (excerpt). Generated results include CKRI references, projection of bathymetric / topographic results, and further knowledge for respective areas.

features [19], chronologies, spatial information, and Volcanic Explosivity Index (VEI) [20].

All integration components, for all disciplines, require an *explicit and continuous formalisation* [21] *process*. The formalisation includes computation model support, e.g., *parallelisation standards, OpenMP* [22], Reg Exp patterns, e.g., *Perl Compatible Regular Expressions (PCRE)* [23].

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) [24] deploying the Generic Mapping Tools (GMT) [25] for visualisation.

Prehistoric objects and contexts are taken from *The Prehistory and Archaeology Knowledge Archive (PAKA)*, in continuous development for more than three decades [26] and is

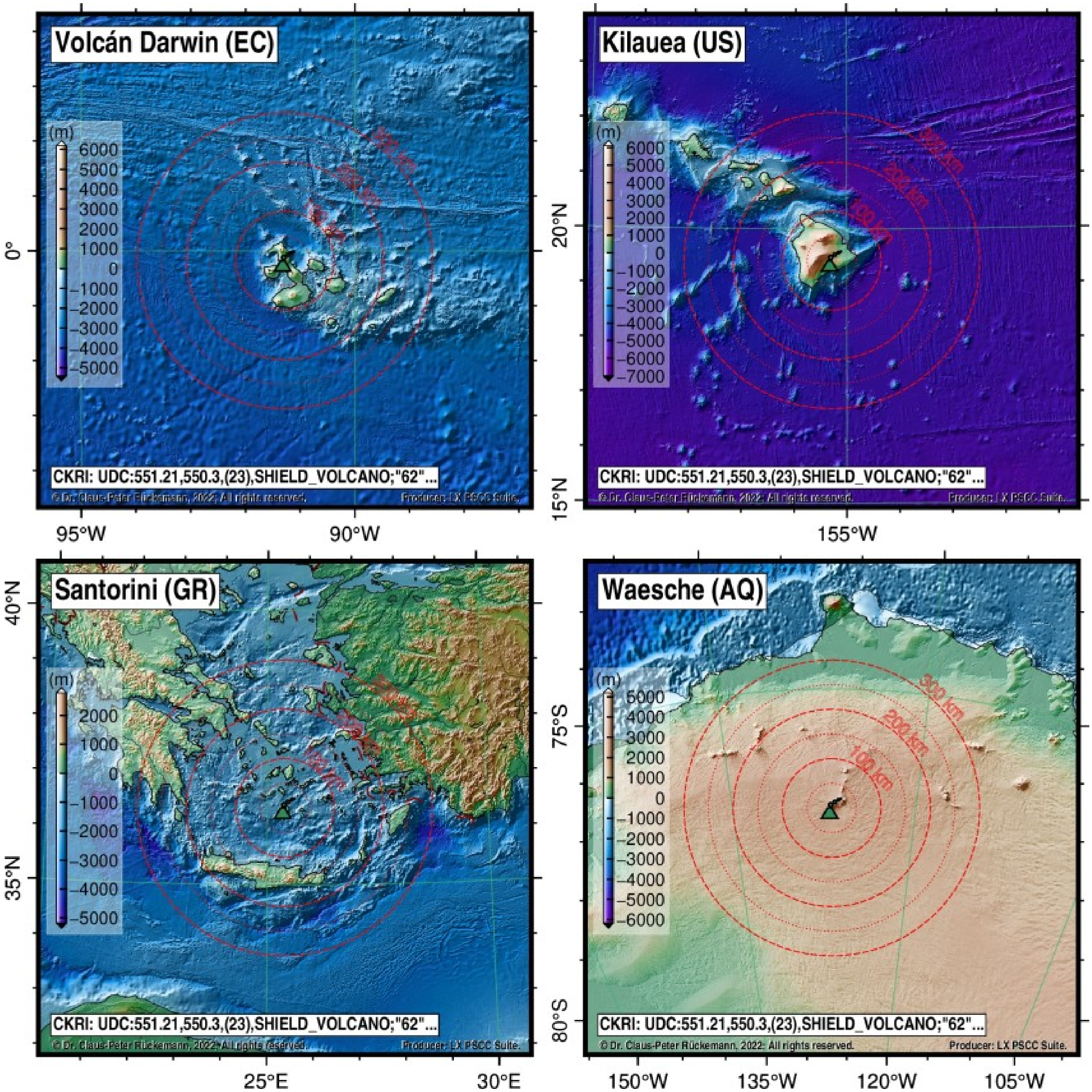

Figure 3. Resulting symbolic representation of a volcanological features group facet (shield volcano) based on coherent conceptual knowledge integration (excerpt). Generated results include CKRI references, projection of bathymetric / topographic results, and further knowledge for respective areas.

released by DIMF for the previous working edition [17] and the contributions for this work [27].

Several coherent systems of major natural sciences' context object groups from *KR realisations* have been implemented, especially Knowledge Resources focussing on volcanological features [20] deployed with in depth contextualisation [19] and with a wide range [16] of contexts [15] and structures [28].

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) [29] data fusion [30], HR Digital Chart of the World (DCW) [31], and Global Self-consistent Hierarchical High-resolution Geography (GSHHG) [32]. SRTM was produced under the National Aeronautics and Space Administration (NASA) Making Earth System Data

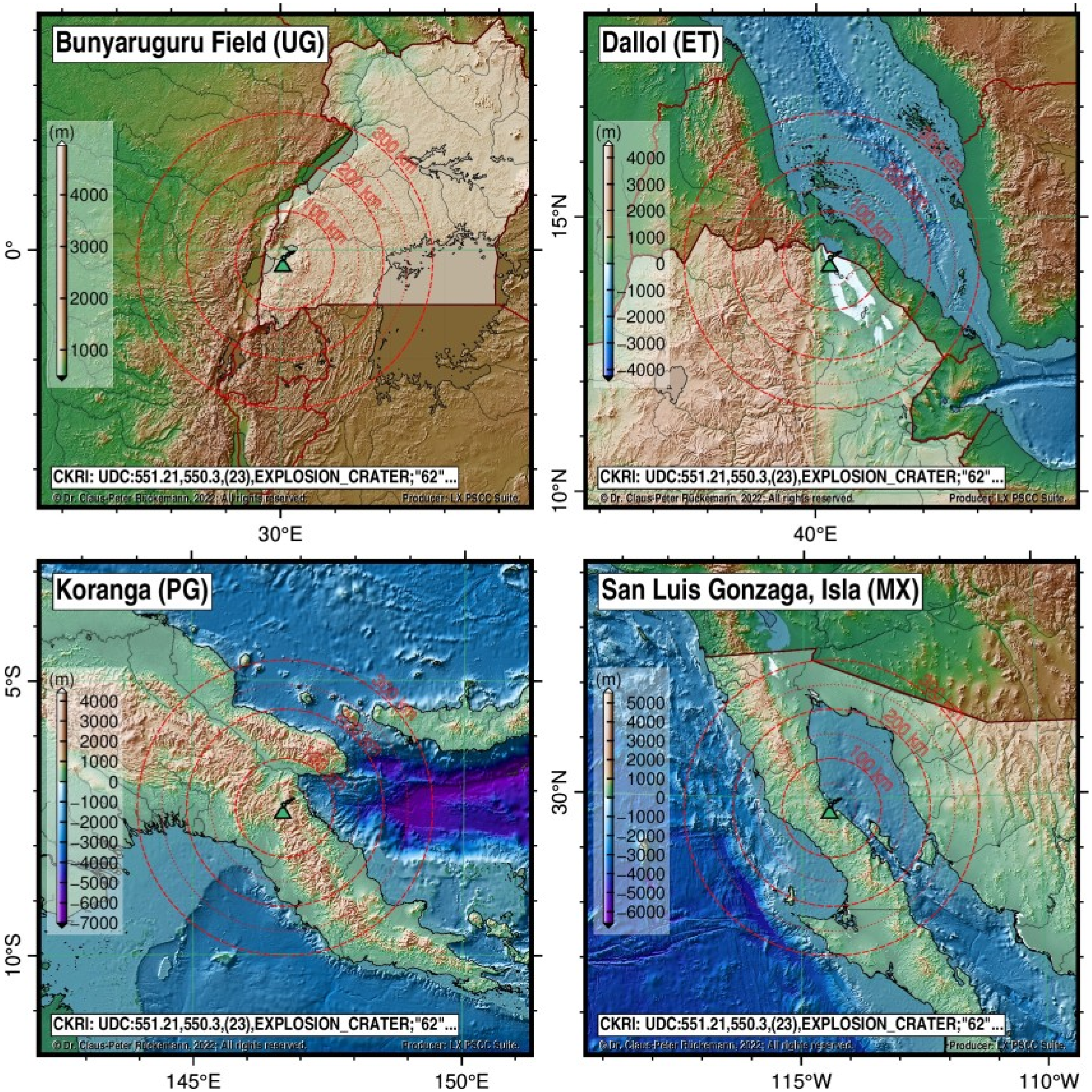

Figure 4. Resulting symbolic representation of a volcanological features group facet (explosion crater) based on coherent conceptual knowledge integration (excerpt). Generated results include CKRI references, projection of bathymetric / topographic results, and further knowledge for respective areas.

Records for Use in Research Environments (MEaSUREs) program. The Land Processed Distributed Active Archive Center (LPDAAC), USA [33], 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 [34] and site [35]. SRTM15 Plus [30] is continuously updated and improved [29].

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 [28]. 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* [36]

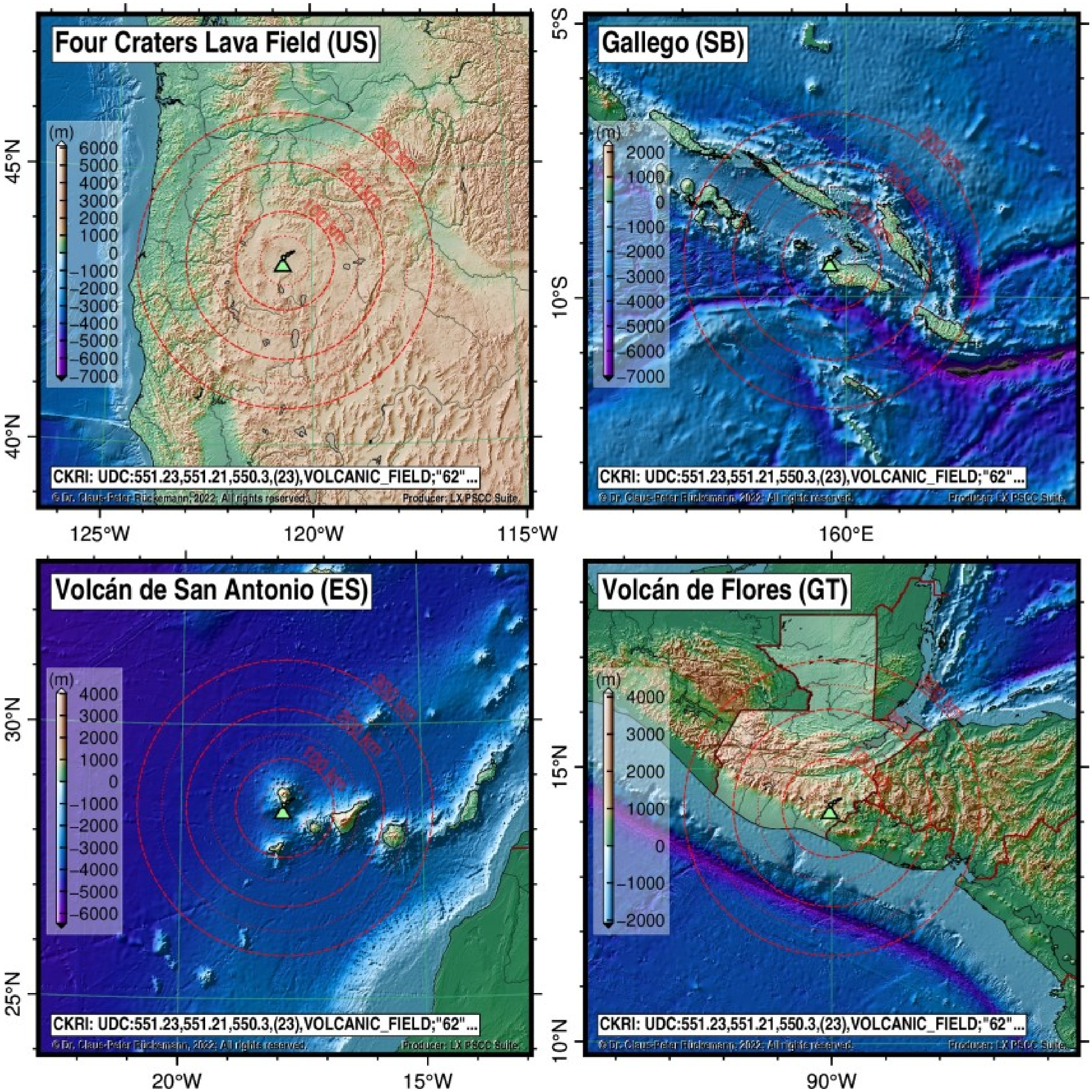

Figure 5. Resulting symbolic representation of a volcanological features group facet (volcanic field) based on coherent conceptual knowledge integration (excerpt). Generated results include CKRI references, projection of bathymetric / topographic results, and further knowledge for respective areas.

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.

VI. Discussion

Implementation and realisation provide a coherent conceptual contextualisation and a seamlessly coherent conceptual knowledge integration and faceting with any available knowledge resources.

The methodology and its implemented methods proved to enable sustainable, advanced contextualisation [37] and method integration [38], e.g., for prehistorical and classical archaeology and their multi-disciplinary contexts.

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.

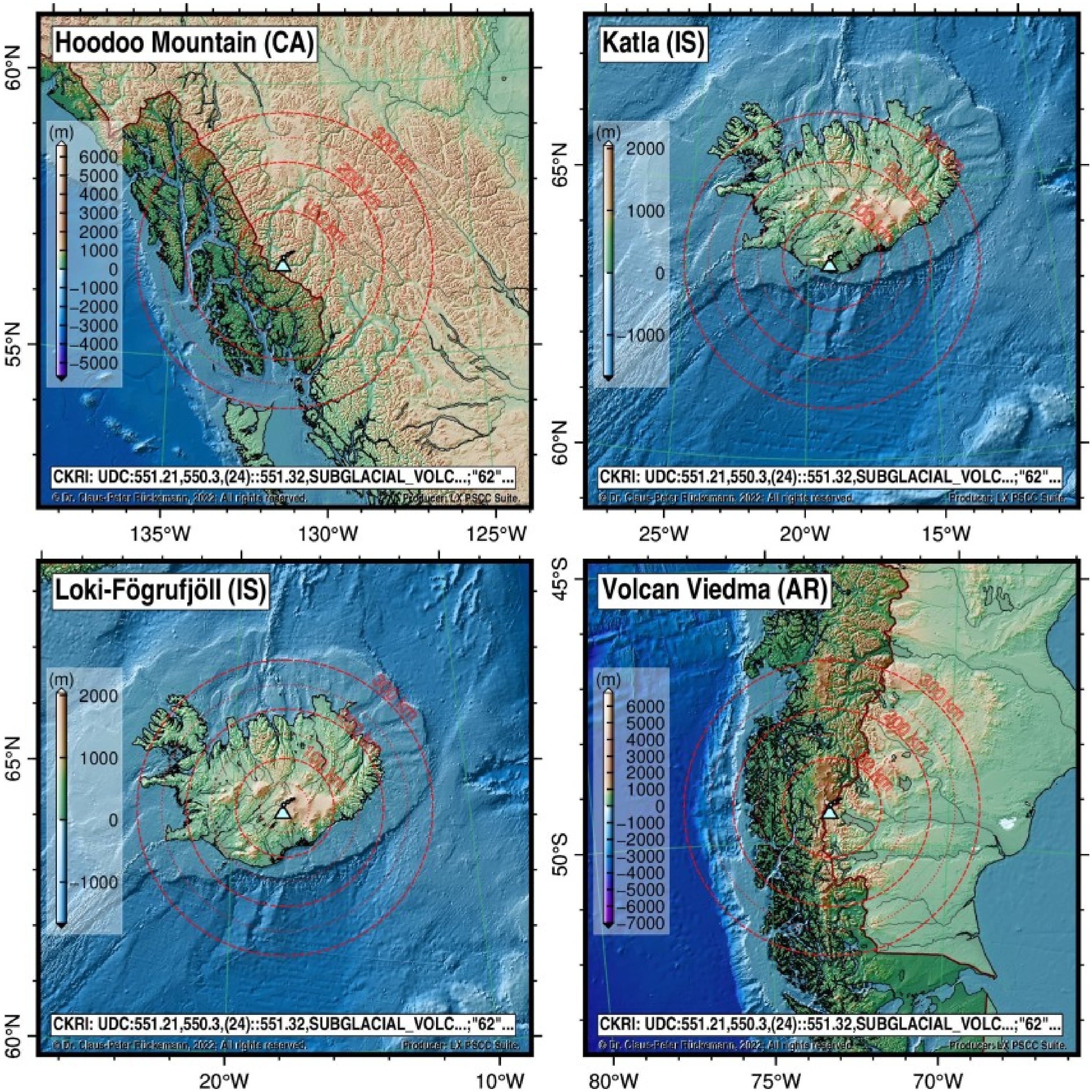

Figure 6. Resulting symbolic representation of a volcanological features group facet (subglacial volcano) based on coherent conceptual knowledge integration (excerpt). Generated results include CKRI references, projection of bathymetric / topographic results, and further knowledge for respective areas.

- 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 [22] and job parallel procedures.

The CRI framework components allow efficient paralleli-

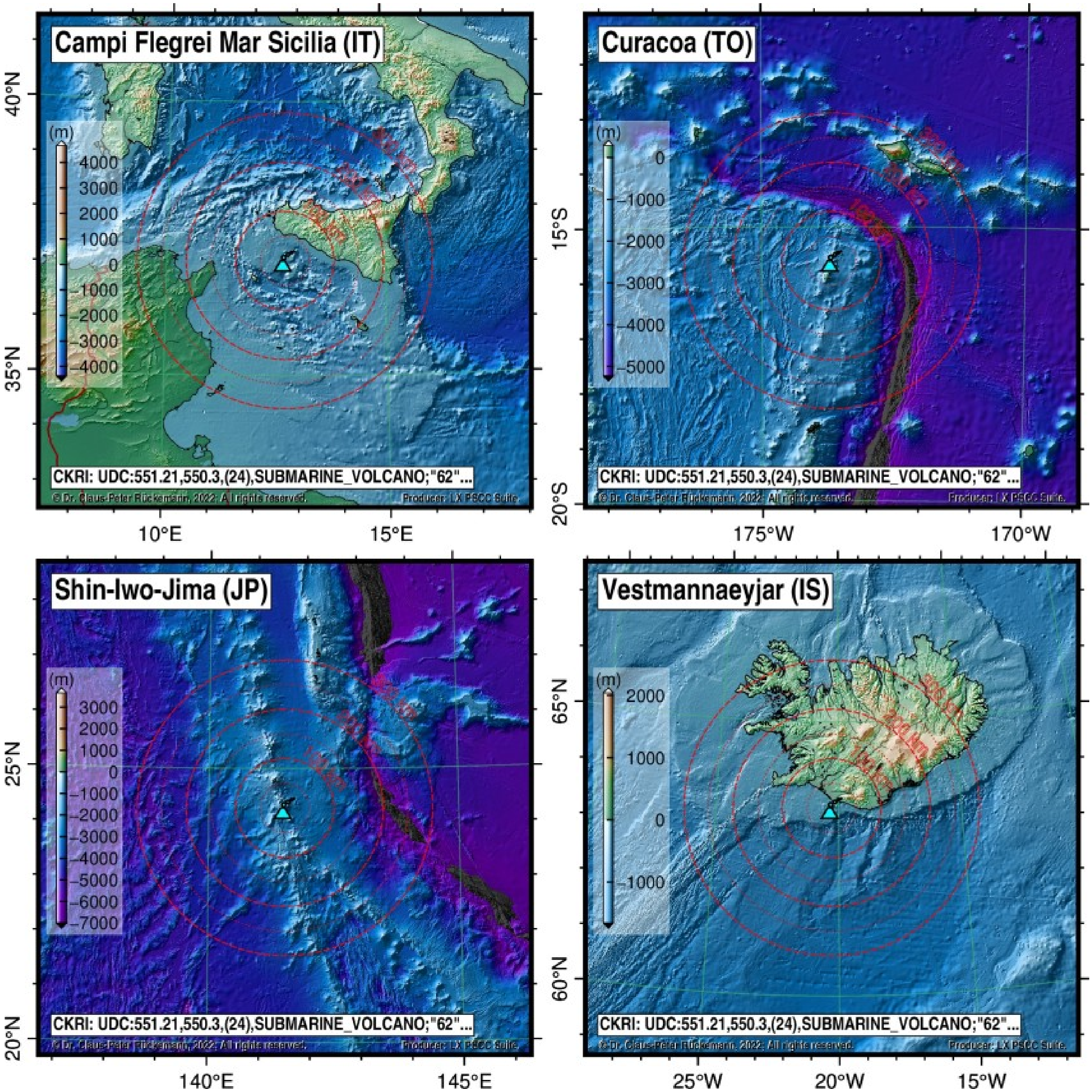

Figure 7. Resulting symbolic representation of a volcanological features group facet (submarine volcano) based on coherent conceptual knowledge integration (excerpt). Generated results include CKRI references, projection of bathymetric / topographic results, and further knowledge for respective areas.

sations 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.

The CKRI and the CRI framework enable flexible, systematical, and sustainable multi-disciplinary contextualisation from methodology to realisation, e.g.,

- semi-automated referencing,
- chorology views,
- chronology views,
- multi-disciplinary contexts,
- automated symbolic representation, e.g., graphical representation and visualisation,
- sustainable standardised components,

and a myriad of further features.

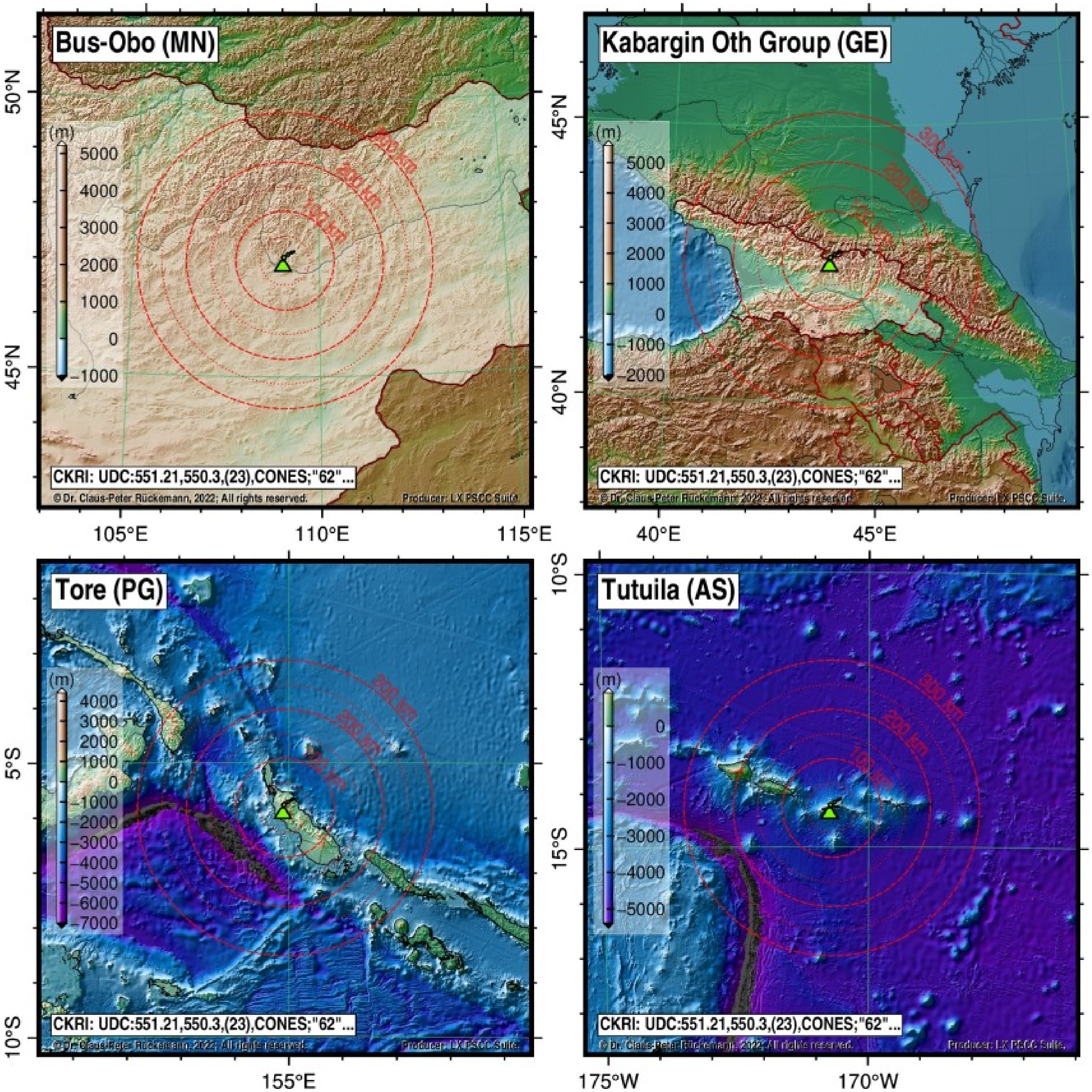

Figure 8. Resulting symbolic representation of a volcanological features group facet (cones) based on coherent conceptual knowledge integration (excerpt). Generated results include CKRI references, projection of bathymetric / topographic results, and further knowledge for respective areas.

Together with the corresponding procedural component framework implementation, the CKRI 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.

VII. Conclusion

Employing the methodology of coherent conceptual knowledge contextualisation for developing a coherent context integration in prehistory and archaeology proved effective, efficient, scalable, and sustainable during all long-term development and practical use.

The goal of creating a practical Holocene-prehistoric inventory of worldwide volcanological features groups facets 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.

Procedural knowledge and realisation aspects, e.g., component framework, data integration from prehistory and ar-

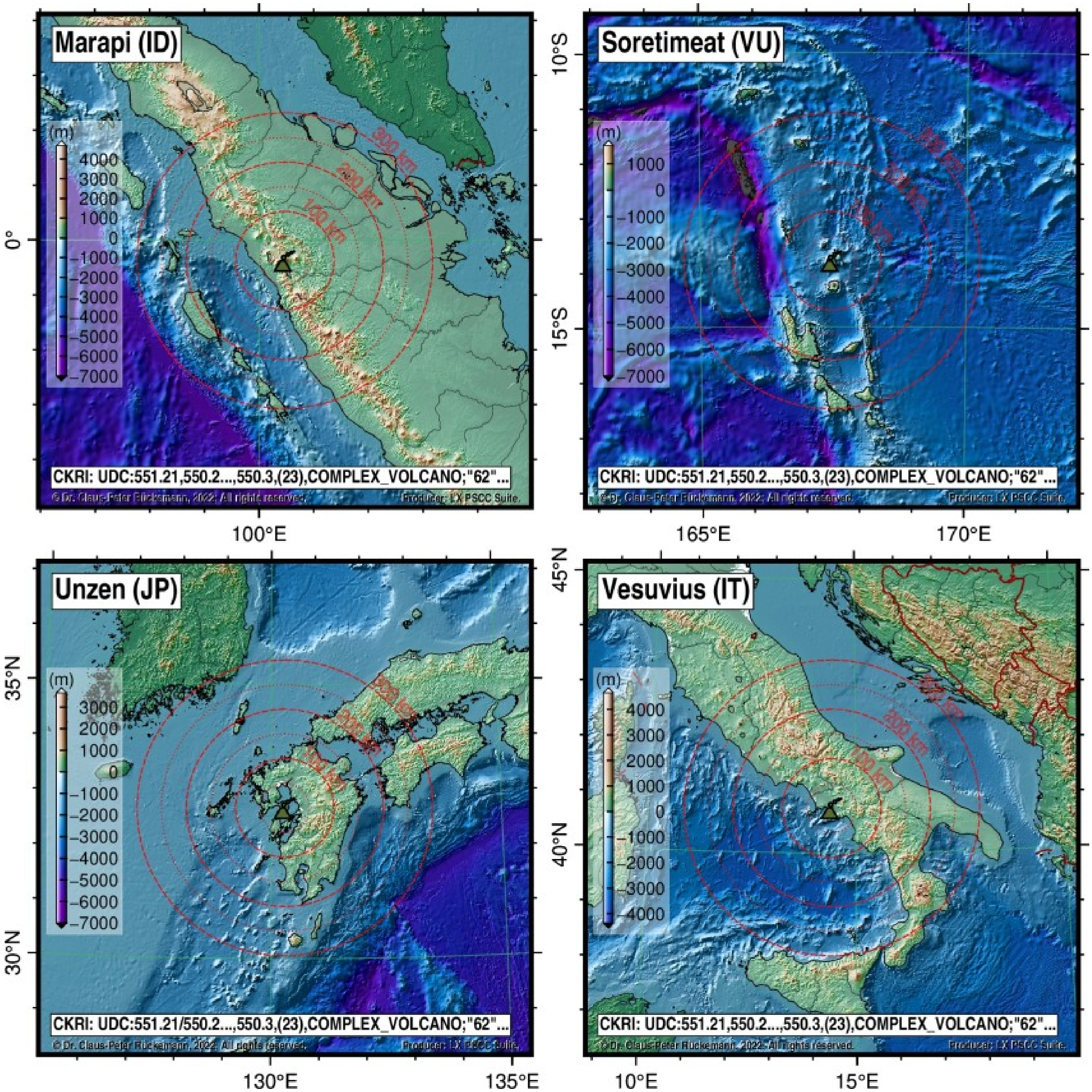

Figure 9. Resulting symbolic representation of a volcanological features group facet (complex volcano) based on coherent conceptual knowledge integration (excerpt). Generated results include CKRI references, projection of bathymetric / topographic results, and further knowledge for respective areas.

chaeology, satellite data processing, and further parallelisation development, are addressed by a separate long-term research work package [5].

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 work will address the resulting and continuously further developed Holocene-prehistoric inventory of worldwide volcanological features, continuous resources development, coherent multi-disciplinary conceptual knowledge contextualisation, new advanced multi-dimensional context integration models, and integration with prehistorical and archaeological knowledge resources, e.g., with the ongoing multi-disciplinary development of PAKA [17], including further georeferencing and spatial processing.

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