

ECP-2007-GEO-317001

OneGeology-Europe

Scientific, Semantic and Geometric Harmonisation of Spatial Geological Data in Europe

- Issues and Recommendations -

Objective of this document

This document explains the issues encountered during scientific, semantic and geometric harmonisation of the 1:1 million geology data within Europe upon the OneGeology-Europe project. It includes a number of recommendations for future work between the various EU Geological Surveys post project. Harmonisation is not unique to geoscience and crosses a large number of scientific disciplines projects within the European Union, it is hoped that some of the guidance and processes identified within this report can constructively feed into EC/EU work tasks tackling harmonisation issues.

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¹ OJL 79, 24.3.2005, p.1

Executive Summary

OneGeology-Europe is delivering a web-accessible, semantically and technically interoperable geological dataset with “progress towards harmonisation”. This report highlights the issues that need to be tackled to scientifically harmonise geological data from the many distributed data sources across political boundaries. This encompasses mainly semantic and geometric issues but also issues related to both management and communication.

Scientific and cooperative methods for the harmonisation process are described and underpinned by examples developed by the Work Package 3 members of OneGeology-Europe. In addition, aspects of the development and use of technical harmonisation tools are being discussed. The report ends with a number of conclusions and recommendations for future harmonisation endeavours from the distributed data sources, specifically in the context of the EC INSPIRE Directive.

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1. Introduction

1.1 Overview of OneGeology-Europe (1G-E)

OneGeology-Europe (1G-E) is making geological spatial data held by the geological surveys of Europe more easily discoverable and accessible via the internet.

Geological spatial data is essential for the prediction and mitigation of landslides, subsidence, earthquakes, flooding, and pollution. These issues are global in nature and their profile has also been raised by the OneGeology global initiative for the International Year of Planet Earth 2008.

'Geology' is also a key dataset in the EC INSPIRE Directive (Annex II); and fundamental to the Annex III Themes of natural risk zones, energy and mineral resources.

Rich geological data sets exist in the Geological Survey of each individual EC Member State, but for those outside the geological surveys they are difficult to discover, to obtain and to understand. In addition the datasets from different Geological Surveys differ considerably with respect to their contents, description and geometry and are therefore not interoperable.

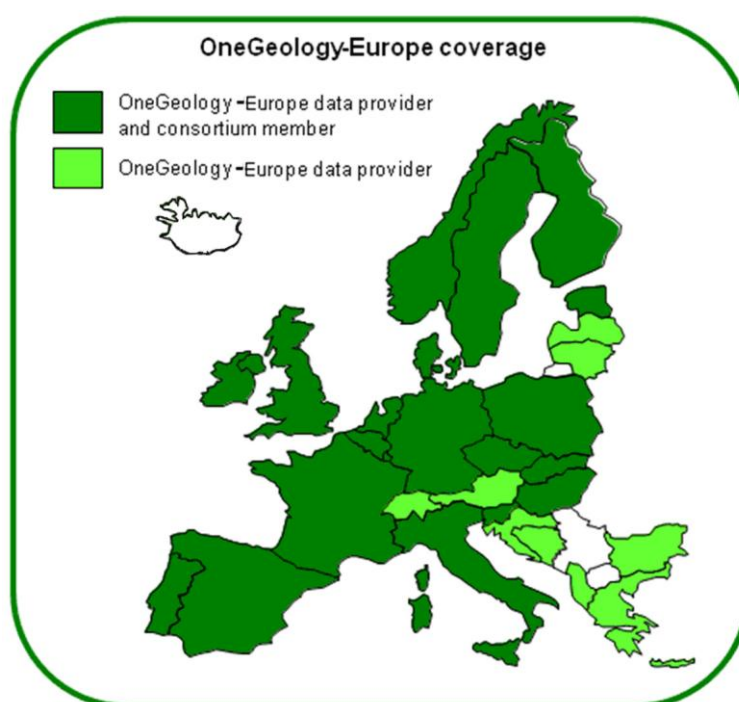


Figure 1-1: Participating countries in OneGeology-Europe.

The 1G-E project is delivering a web-accessible, interoperable geological spatial dataset for the whole of onshore Europe (fig 1-1) at 1:1 million scale based on existing data held by the European geological surveys (specifically composition and structure of the surface geology). To enable the interoperability of the datasets, a common vocabulary and portrayal specification for basic geological map data has been developed. This forms the vital foundation for the harmonisation of these disparate datasets.

Each participating Geological Survey provides access to its data via the internet, by implementing and hosting an interoperable web service to deliver their national geological data in a semantically harmonised form. It is important to note that the original national databases, internal classifications and the vocabulary remain unchanged. The 1G-E data model is implemented in GeoSciML which enables the sharing and exchange of the data within and beyond the geological community of Europe. 1G-E therefore accelerates the development and deployment of this nascent international interchange standard for geological data.

1G-E is addressing the multilingual aspects of access through a multilingual discovery portal, so that awareness and interest is raised in both the user and data provider communities. Thus the project is moving geological knowledge closer to the end-user where it will have greater societal impact and ensure fuller exploitation of a key data resource gathered at considerable public expense. Users of 1G-E will be able to discover, view and download geological data from across the European Union.

Due to the sharing of geological knowledge and data across Europe, 1G-E is helping to facilitate the re-use and addition of value by a wide spectrum of users both in the public and private sectors. In addition, the project is providing examples of best practice in the delivery of digital geological spatial data to users, e.g. in the insurance, property, engineering, planning, mineral resource and environmental sectors.

Last but not least, 1G-E will be a test case for the geology theme (Annex II) and other related themes of the implementation of the INSPIRE Directive. This may not only benefit the geology theme itself, but will also provide a template for other environmental data themes. Thus 1G-E will provide a reference base on which other valuable data products and services can be built. 1G-E is importantly ensuring that Europe plays a leading and pivotal role globally in the development of a geoscience spatial data infrastructure (SDI) and making a major and making a significant contribution to INSPIRE.

1.2 Harmonisation and Interoperability

Each geological survey in Europe (and across the world) has, over two centuries, developed its own national way to map, describe and portray their geological map units. In the last twenty years different methods of modelling and describing the digital data have also been developed.

The need for harmonised European geological data was previously recognised in the year 1881 at the second International Geological Congress in Bologna, where the first cross-boundary international mapping project of Europe started: The International Geological Map of Europe and the Mediterranean Regions at the scale 1:1'500'000. This substantial international endeavour was finally completed in 2000 (BGR and UNESCO) and was soon followed by the completion of the first harmonised digital spatial dataset of Europe - the 1 : 5 Million International Geological Map of Europe (Asch, 2005) which was also published as a paper map. The data compilation of the geology for these two map projects was carried out and coordinated centrally at the Federal Institute for Geosciences and Natural Resources (BGR), Germany, and its predecessors under the Umbrella of the Commission of the Geological Map of the World (CGMW) in cooperation with European Geological Survey organisations and universities.

Unlike these previous projects, 1G-E is built upon a distributed digital model that leaves the data with the responsible Geological Survey organisation, which provides access via the internet as web services or through the geportal.

Geology does not recognise political boundaries, however, from one country to another the properties of the same rock formations will, with a high probability, be described differently (e.g. regarding the lithology, the age, or the genesis). Furthermore, the rock formations will be portrayed with differing colours and symbols (fig. 1-2).

The European Commission and many users require consistent geological data, which does not change its attributes or portrayal as it crosses political boundaries. The EC INSPIRE Directive, as well as the EC Water and Soil Directives are specifically addressing these issues. Thus, harmonised and interoperable data sets for the whole of Europe are essential.

Different levels of interoperability exist from data systems, through data language, data structure to data content. The first two levels are addressed by standardisation bodies such as the Open Geospatial Consortium (OGC) and are common to all domains. The upper two levels are however domain specific and need to be developed by the relevant domain communities. Schematic interoperability in the geosciences has been addressed by the development of GeoSciML which provides a common data model and Markup Language. However to achieve full interoperability not only does the data structure need to be harmonised but also the data content. This is commonly referred to as semantic harmonisation.

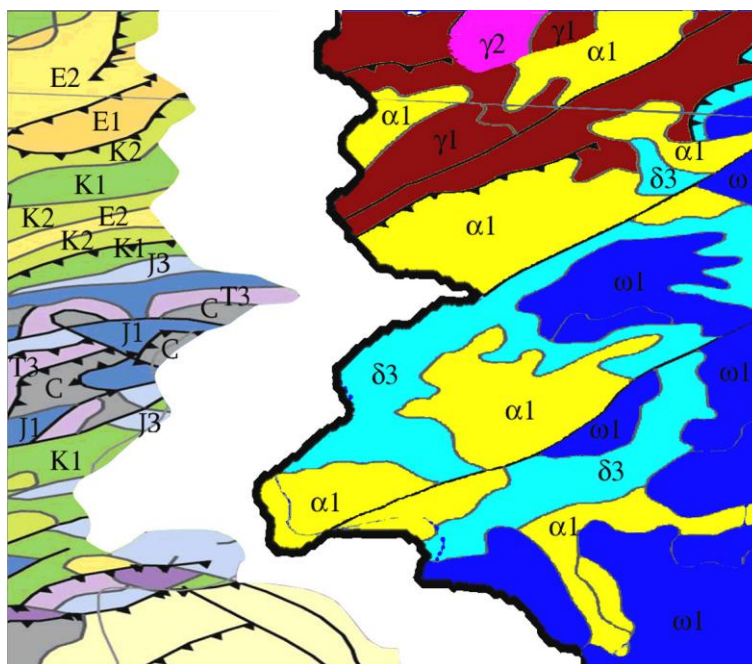


Figure 1-2: Sketch showing the possible differences in the semantic description, the geometry and the portrayal of geological spatial data.

The 1G-E project is delivering a schematically interoperable geological spatial data set, using GeoSciML, for the whole of onshore Europe at 1:1 million scale, with progress towards harmonisation.

Semantic harmonisation implies agreement on the usage of the same concepts to describe a map feature such as a geologic unit. It is important to note that it is the concept definition, rather than the concept label, which needs to be standardised. For example the term ‘clay’ is labelled differently in several European countries (“argillia” in Italy, “Ton” in Germany) but it is its definition which needs to be entirely conformant.

Two further levels of harmonisation are possible and have been attempted in OneGeology-Europe. Geometric harmonisation involves aligning polygons and geologic structures across national borders. The final level of harmonisation is to provide a common portrayal (fig. 1-3).

The data harmonisation process generally requires data generalisation.

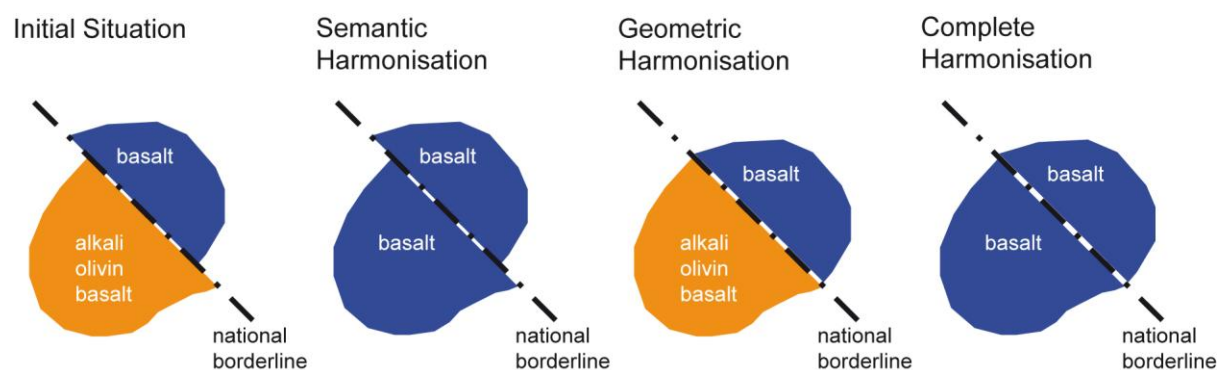


Figure1-3: Sketch showing the difference between semantic and geometric harmonisation.

2. Generic Harmonisation Issues

There are approximately 9000 kilometres of political boundaries between and around the 1G-E participating countries, and so there are many challenges regarding the harmonisation of geological units from country to country. Semantic and geometric discrepancies of the units and lineaments occur almost every kilometre. In building a huge distributed data set for the whole of Europe for the 1G-E project, these harmonisation issues can only be tackled in example areas that illustrate “progress towards harmonisation”.

Apart from a couple of exceptions (UK and Ireland, Portugal and Spain) each country has many neighbours, and geological formations can easily spread over more than two countries.

The most commonly occurring harmonisation issues, both semantic and geometric, are described in the following sections. Most harmonisation issues are a combination of both semantic and geometric.

2.1 Semantic and Geometric Harmonisation Issues

The essential basis for any semantic harmonisation is the agreement and the usage of common vocabularies. For 1G-E such a generic geology data specification was developed on the basis of the global Commission for Geoscience Information (CGI) vocabularies (see D3.1 WP3 Data Specification Report; fig. 2-1).

The 1G-E vocabularies contain 516 defined terms and definitions on lithology, geologic age, genesis, contacts and structures. These terms and definitions were reviewed by 20 project partners (Geological Surveys), the CGMW and the CGI with 532 comments resulting. Over a hundred new terms and definitions were fed into the global CGI vocabulary. This uniform and common vocabulary enables consistent description of geologic information and is therefore the basis for semantic interoperability. The vocabulary was derived from the OneGeology-Europe requirements developed by WP 3 and a subset of the global CGI Vocabulary.

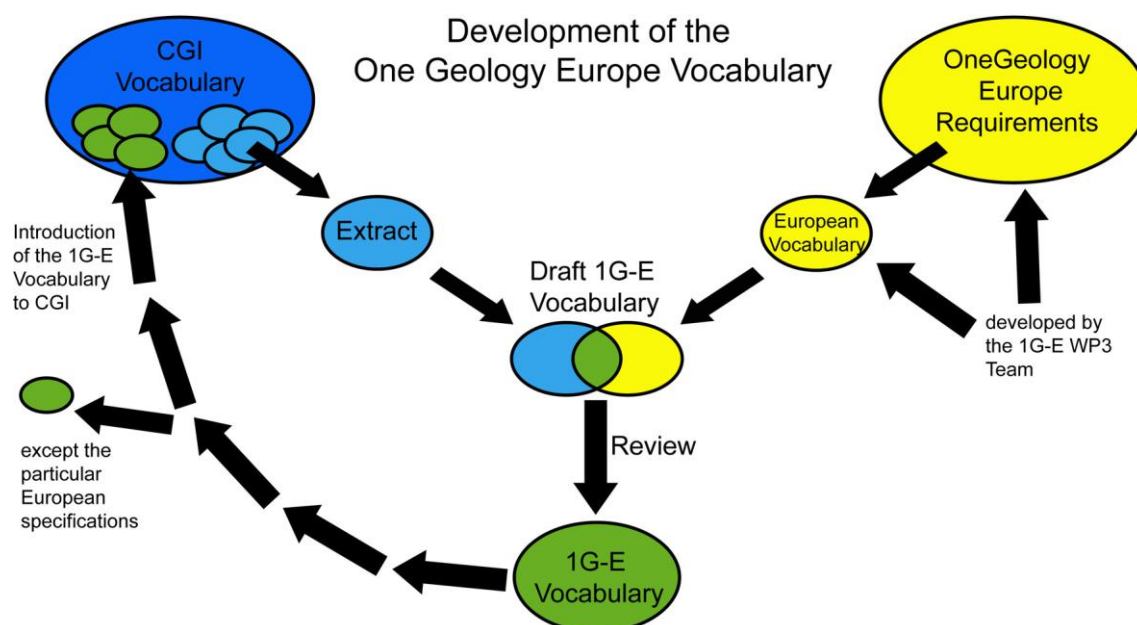


Figure 2-1: Schematic presentation of the development of the 1G-E vocabulary.

Geometric harmonisation issues are due to polygons on the geological map that do not fit geometrically across national boundaries. The essential foundation for geometric harmonisation is a common geographic base for the geological datasets. In the case of 1G-E this is the EuroGlobalMap product produced by Eurogeographics. Small discrepancies in the political boundaries between different countries can result in significant geometric displacements of the data set (see also section 2.2).

Despite this excellent foundation, semantic and geometric harmonisation issues still occur.

2.1.1 Differing level of detail

One frequently occurring semantic harmonisation issue is connected to the level of detail, which are used to describe a geological unit. In 1G-E this problem appears mainly in the “age” layer of the data set due to the usage of both the (higher level) “Epoch” and (the lower level) “Stage” for the characterisation of the age of a rock. This differing degree of detail may be the result of different scales of the original source maps, but may also be due to different national age classifications.

Figure 2-2 shows the geological age units at the boundary between France and Germany near Saarbrücken/Metz. France uses the (upper) less detailed “Epoch” level (Early/Lower Triassic, Middle Triassic, Late/Upper Triassic) to characterise the age of their geological units, whereas Germany works with the more detailed (lower) “Stage” level (Induan, Olenekian, Anisian, Ladinian).

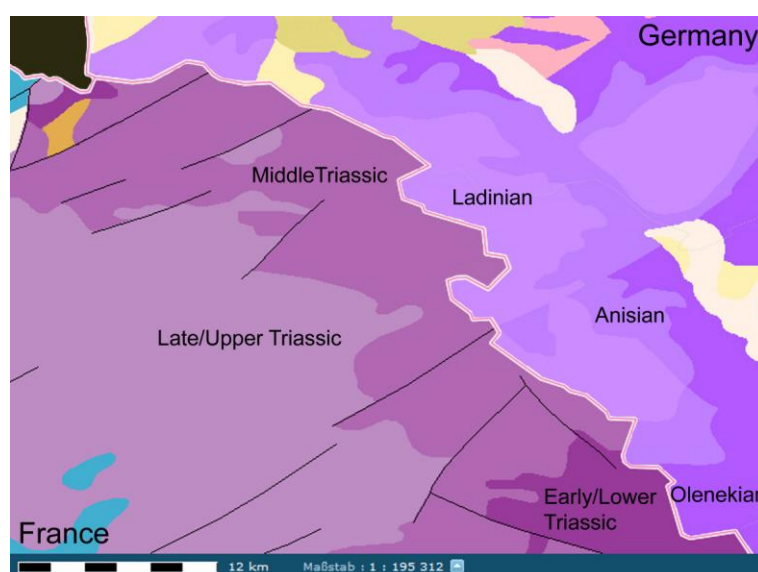


Figure 2-2: Screenshot of the French-German boundary near Saarbrücken/Metz showing the semantic harmonisation issue due to the usage of different levels of detail in the description of the age of a geologic unit.

The different degree of detail not only poses a problem in the age characterisation, but also in the lithological description (i.e. the characteristics of the rock) of a geologic unit. This is the case for example at the Western part of the Danish and German boundary. Denmark describes the main lithology as Mud, Germany as predominantly Clay with subordinate Silt and Sand (see Figure 2-3 below). In accordance with the 1G-E vocabulary Clay and Silt are subcategories of Mud. Therefore in this case Germany described their lithologies in greater detail than Denmark.



Figure 2-3: Screenshot of the Danish-German boundary showing the semantic harmonisation issue due to the differing usage of the hierarchy level of the Lithology portrayal.

2.1.2 Differing predominant lithology

Another very common semantic harmonisation issue is the differing determination of a dominant lithology, especially in heterogenic geologic units. At the boundary of Italy and Slovenia near Cividale/Tolmin this problem can be seen: Italy describes the lithology of their geologic units as predominant Limestone with subordinate Dolomite, whereas Slovenia characterises the lithology of the same geologic unit vice versa (predominant Dolomite and subordinate Limestone). The lithology of the second major geologic unit is termed by Italy as predominant Dolomite with subordinate Impure Limestone and by Slovenia as Impure Carbonate sedimentary Rock with subordinate Clastic Sedimentary rock (Fig. 2-4).

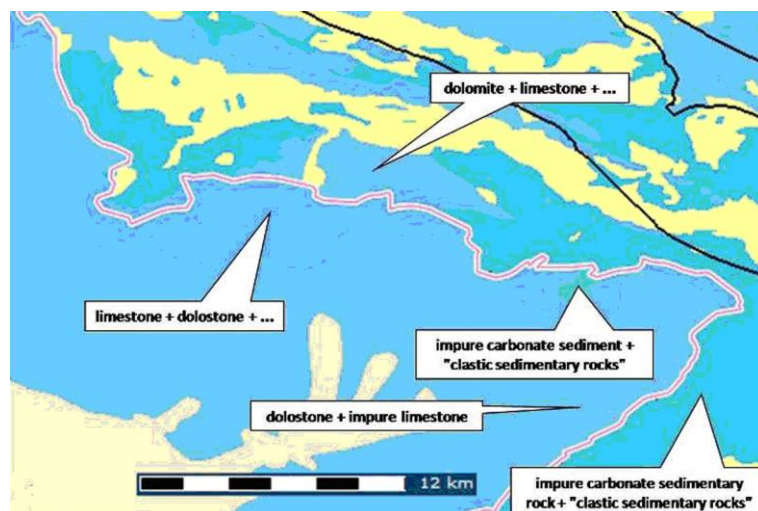


Figure 2-4: Screenshot of the boundary of Italy and Slovenia showing the semantic harmonisation issue due to the differing determination of the dominant lithology.

2.1.3 Entirely different description of the same geologic unit

There are numerous other reasons for semantic harmonisation issues that are far more complex and more difficult to resolve than the issues described above. They include the differing description of the same geologic unit.

Figure 2-5 shows for example the French-Italian boundary near Cuneo/Colmar in the alps and the contact of the same geologic unit described to be of Cambrian age by France and of Carboniferous age by Italy. In this particular case the most likely explanation is an error on the part of either Italy or France (or both), for example in the mapping or typing, the usage of old concepts, which are not accurate anymore, the usage of outdated data sets, or the inaccuracy of the original data. Additionally, in such geologically complex and heterogeneous areas like the alps it is very difficult to determine objectively which rock corresponds to the main lithology, especially at 1:1 000 000 million scale where a small polygon may correspond to quite a big area in the field (1 mm on the map is 1 km in the field). Harmonisation issues related to such problems prove to be the hardest to solve, because it is very difficult to determine their origin.

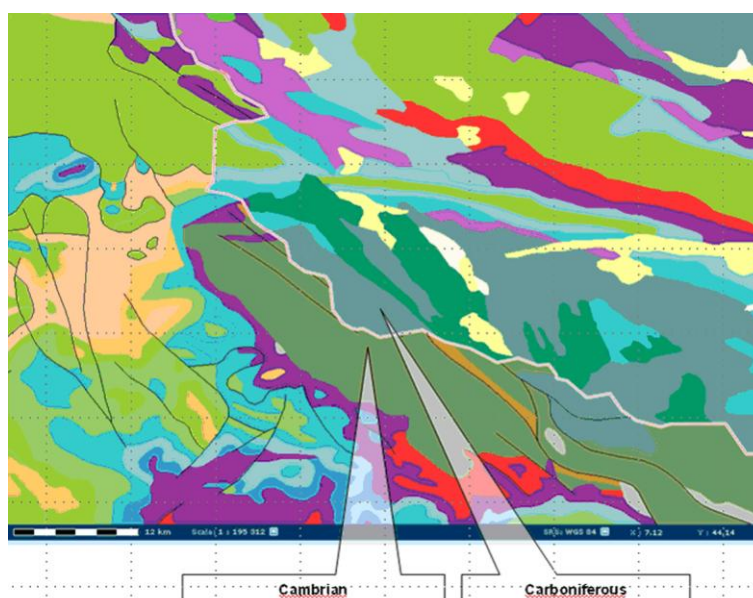


Figure 2-5: Screenshot of the boundary of Italy and France near Cuneo/Colmar showing a complex semantic harmonisation issue, where the same geologic unit is described entirely different by two countries.

One reason for these semantic discrepancies might be due to a difference in the focus of the geological mapping. A country may concentrate their mapping on one aspect of their geology, e.g. the metamorphic rocks, whereas the other country may emphasise for example the Quaternary sediments.

The usage of different (national) geological concepts is another important source of semantic harmonisation issues. The UK for example uses lithostratigraphic units, such as Groups and Formations (e.g. the Tyrone or Argyll Group), as the basis for their geology, which are based on the lithology, the age and the environment. Another example is the German concept of the Triassic. The age transitions of the “Epoch” level of the “German Triassic” (namely Buntsandstein, Muschelkalk and Keuper) do not conform to those of the IUGS Stratigraphic Chart (and therefore do not conform to the 1G-E Age definitions). The resulting harmonisation issue is clearly visible at the border between Germany and France: the usage of these differing national geological concepts results not only in huge semantic harmonisation problems, but also in a displacement of the units of around 6km (Fig. 2-6).

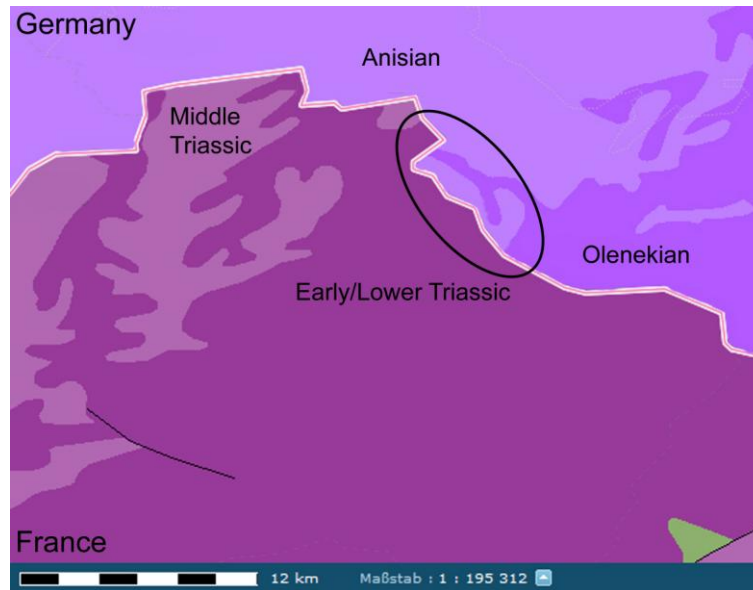


Figure 2-6: Screenshot of the boundary of France and Germany showing the ca. 6 km wide displacement (within the black ellipse) of the same geologic unit due to its description using differing national geological concepts; in this case the “German Triassic”.

The usage of different national concepts is strongly related to different interpretations of a geologic situation. This is another common source for harmonisation issues. One example of such a situation is located in the Czech Republic, Slovakia and Poland. A flysch formation (an association of certain types of rocks) continues throughout all three countries, but each country classifies the flysch units differently, which results in huge discrepancies. Another example is the differing description of metamorphic rocks at the German-Polish boundary. Germany describes the main lithology as orthogneiss, whereas Poland characterises the same unit as a metagranite (Fig. 2-7).

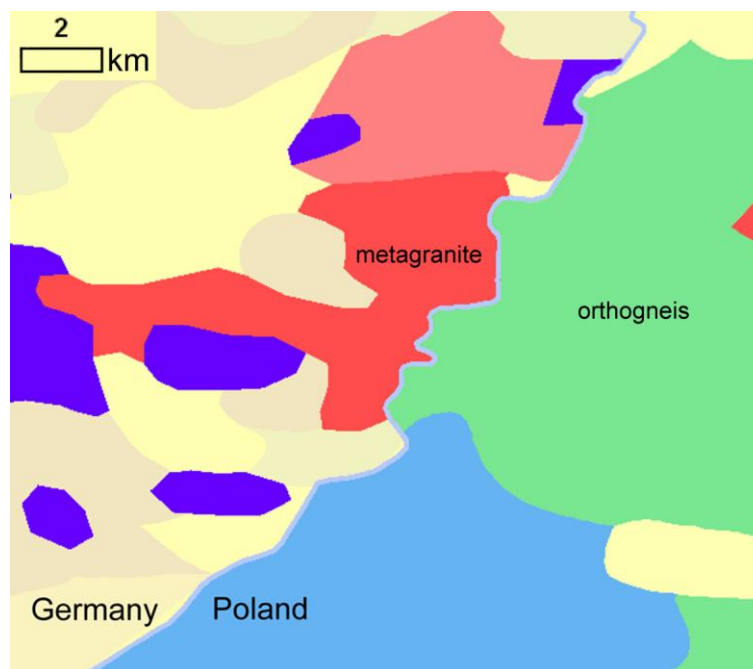


Figure 2-7: Screenshot of the Polish-German boundary showing the semantic harmonisation issue resulting from the differing interpretation and description of a metamorphic unit: Germany described the unit as a metagranite, whereas Poland described the same unit to be orthogneiss.

Such harmonisation issues can often only be solved by the cooperation of regional geologists and additional fieldwork.

2.1.4 Discontinuity of geologic units and structures

The two main harmonisation issues in this category are:

- (a) the displacement of geologic units along the national border and
- (b) the termination of a geologic unit at the national border.

Figure 2-8 shows these two issues at the German-Belgian border near Aachen: (a) a Tremadocian age unit which continues on both sides of the border, but shows small displacements and (b) a Maastrichtian age unit, which is only present on the Belgium side of the border.

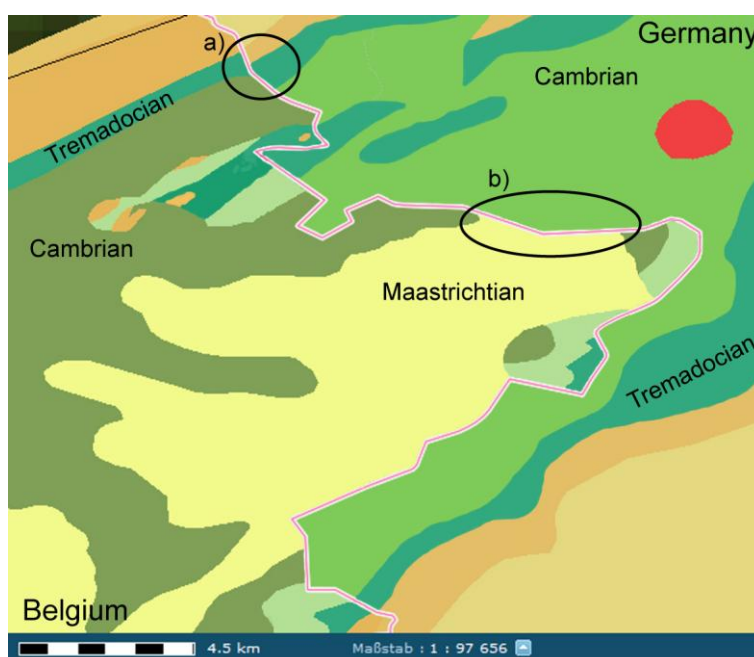


Figure 2-8: Screenshot of the national border between Belgium and Germany (near Aachen) showing the two main geometric harmonisation issues: (a) the displacement of a geologic unit across the national border and (b) the termination of a geologic unit at the border.

These discontinuities of the geologic units across the national borders can have numerous different origins.

2.1.5 Differing scales of the original source data

The main problem, which increases the difficulty of harmonisation significantly, is the differing scales of the national original source maps, which are used to provide the data for 1G-E. The United Kingdom for example traditionally uses a scale of 1:625'000 for their maps; Denmark and Poland use a much larger scale of 1:200'000, which result in more detailed maps; Finland on the other hand uses a scale of 1:2'000'000, thus their maps are less detailed. France, Italy, Germany, Hungary, Portugal and Spain are the only six countries, which have an original map in the same scale of 1:1'000'000 as the aspired data set for 1G-E. These differences in the scales result in huge differences in the degree of detail of the maps, which in turn leads to a variety of semantic and geometric harmonisation issues.

Figure 2-9 shows a screenshot of the Hungarian-Slovakian boundary where the problem of differing original scales is clearly visible. The Slovak Republic used a high resolution background map (1:500 000), whereas Hungary used a background map with a scale of 1:1 000 000 to encode the data for 1G-E.

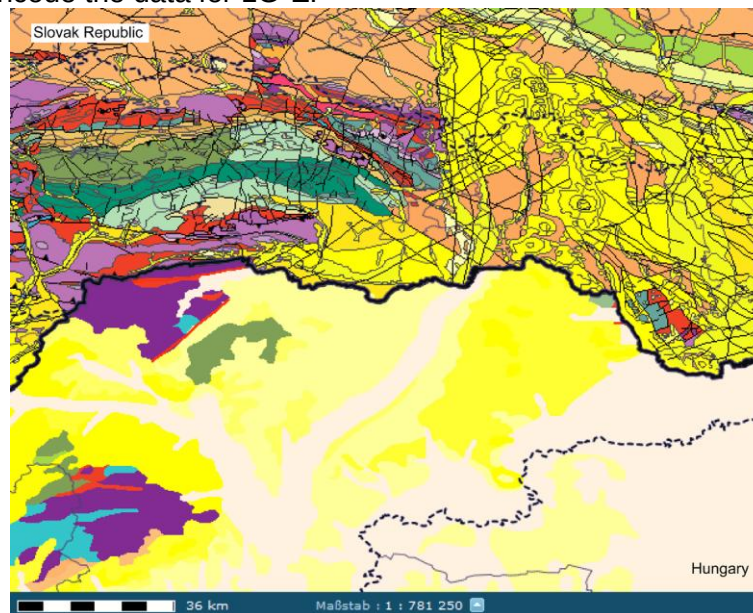


Figure 2-9: Screenshot of the Slovakian-Hungarian boundary showing the geometric and semantic harmonisation issues derived from the difference in the scale of the background maps. The Slovakian map was produced with a background map scale of 1:500 000; that of the Hungarian map with a scale of 1:1 000 000.

2.1.6 Generalisation of the data

Furthermore the different resolutions of the background maps can lead to another problem. By encoding the dataset for 1G-E from a high resolution original map a combination or summary of some units might be necessary and some smaller units may be omitted. This simplification of the data may result in huge differences across the national borders, because each country has an individual focus on the geological units and therefore will decide differently, which and how units are summarised.

Figure 2-10 shows the large semantic and geometric harmonisation issues at the border between Germany and Belgium in the region of the Ardennes. Germany simplified its data more than Belgium by classifying all schistose geologic units in the border area as shale. Belgium, however, distinguished their data as shale, slate, clastic sandstone, siltstone and chalk.

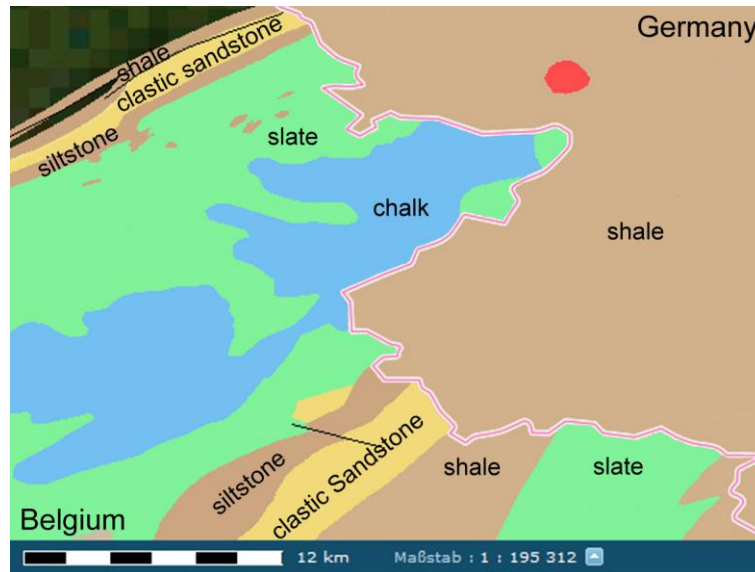


Figure 2-10: Screenshot of the border region of Germany and Belgium in the region of the Ardennes showing the semantic and geometric harmonisation issues derived from the difference in generalisation of high resolution maps.

2.1.7 Differing geographical reference systems

Another reason for geometric harmonisation issues may be due to the usage of different reference systems. During the transformation of the coordinates into a common reference systems rounding errors may arise, which may in turn lead to displacements.

2.2 Issues Related To Data Coverage

Harmonisation issues, which are related to the coverage of data, include misfits of the national boundary of two adjacent countries, gaps in datasets and the difference in treatment of inland water bodies.

The delineation of the political boundary of one country may not coincide with that of the neighbouring country. The mapping of data for a common data set without using a common geographic base thus may produce gaps or overlaps in the data set. Figure 2-11 shows the border between Sweden and Finland. In the southern part data gaps are clearly visible, whereas in the upper part the Finnish data overlaps, i.e. covers the Swedish data.

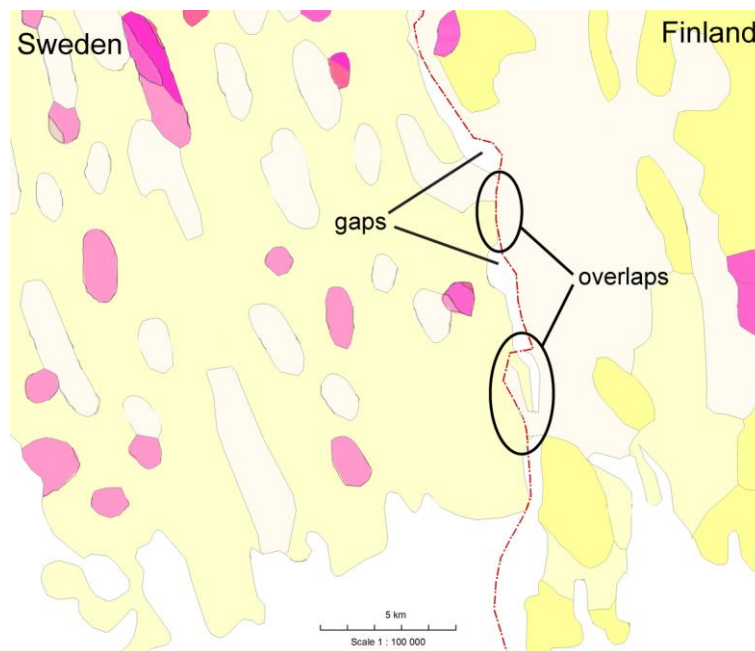


Figure 2-11: Screenshot of the border region of Sweden and Finland showing the impact of the usage of national geographic bases: due to differences in the national boundaries gaps and overlaps are produced.

In some countries it is common to describe the bottom of inland water bodies geologically. Other countries leave such structures free from geologic terms, i.e. mark them as “stream” or “lake”. If such a water body is located in the cross-border region, this difference in treating geographic structures can lead to severe harmonisation issues. An example is visible at the German-Danish border: Denmark classified their rivers deposits to be mainly composed of peat, Germany did not describe them separately (fig. 2-12).

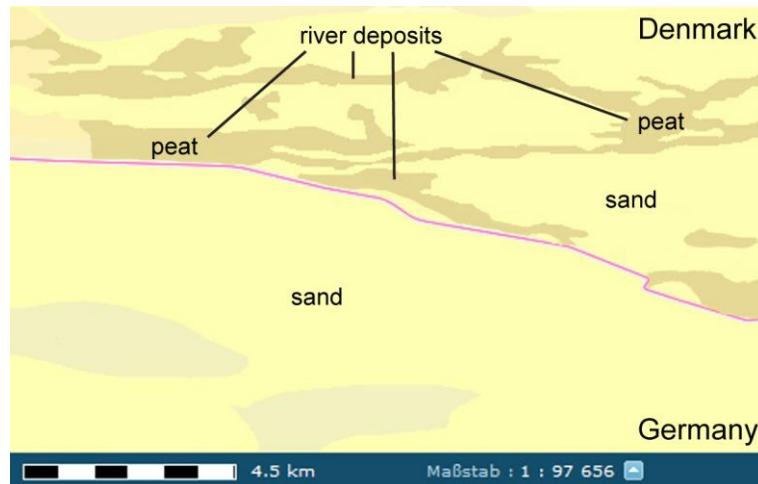


Figure 2-12: Screenshot of the border region of Germany and Denmark showing the semantic and geometric harmonisation issues due to the difference in treating inland water bodies. Denmark characterised the streams to be Peat, whereas Germany did not describe them separately.

It can also happen that data for a certain area within a country is missing. These gaps might be due to political reasons, technical problems or due to the fact that the area is not mapped. One example of such a gap, where no harmonisation is possible, is at the German-Belgium border near Aachen (fig. 2-13).



Figure 2-13: Screenshot of the border region of Belgium and Germany near Aachen, where no data is available on the Belgium side and therefore no harmonisation is possible.

2.3 Communication and Management Issues

Harmonising the data across many political boundaries implies collaboration with many nations and taking into account their understanding of the issues. This means coping with the challenge of combining the national standards of (in the case of 1G-E) 20 different countries, combining the working methods of these geological survey organisations. Both have not always proved easy due to the differences in the professions and social values of the people working on the project. A common acceptance of the needs, an agreed aim and working rules (e.g. deadlines) of the project is therefore essential, especially if there is only short time available, for the project to be successful.

Another interesting point is the communication between all the participants. The technical means, i.e. working with standard software such as MS Word, MS PowerPoint, ESRI GIS etc. can be standardised, however as the common project language (English) was not the first language of many of the participants this has provided some scope for misunderstanding.

For 1G-E, Work Package 3 acts as a link between the scientific and technical work packages, which poses a further issue: geologists and computer scientists tend not to speak the same language, each having its own concepts and acronyms.

Finally, there are regions within Europe, which are not “covered” by a particular Geological Survey, e.g. the Channel Islands, Gibraltar or Andorra.

3. Methods developed by 1G-E for the Harmonisation Process

3.1 Scientific and Cooperative Solutions

To facilitate a successful harmonisation the following pre-conditions are required:

- (a) all datasets need to be adapted to the same common geographic base, so that all harmonisation issues related to topology and the coordinate reference system should be resolved and
- (b) all geological units and structures need to be described with the same vocabularies.

To fulfil these requirements, Work Package 3 developed a specific European 1G-E Data Specification, all data sets were encoded according to that vocabulary and mapped to the EuroGlobalMap product (Eurogeographics).

To resolve the harmonisation challenges described in chapter 2 it is essential to define a workflow for the harmonisation as well as to agree upon rules. The schema shown in figure 3-1 presents such a workflow for the harmonisation process. In the following sections the actions will be described in detail.

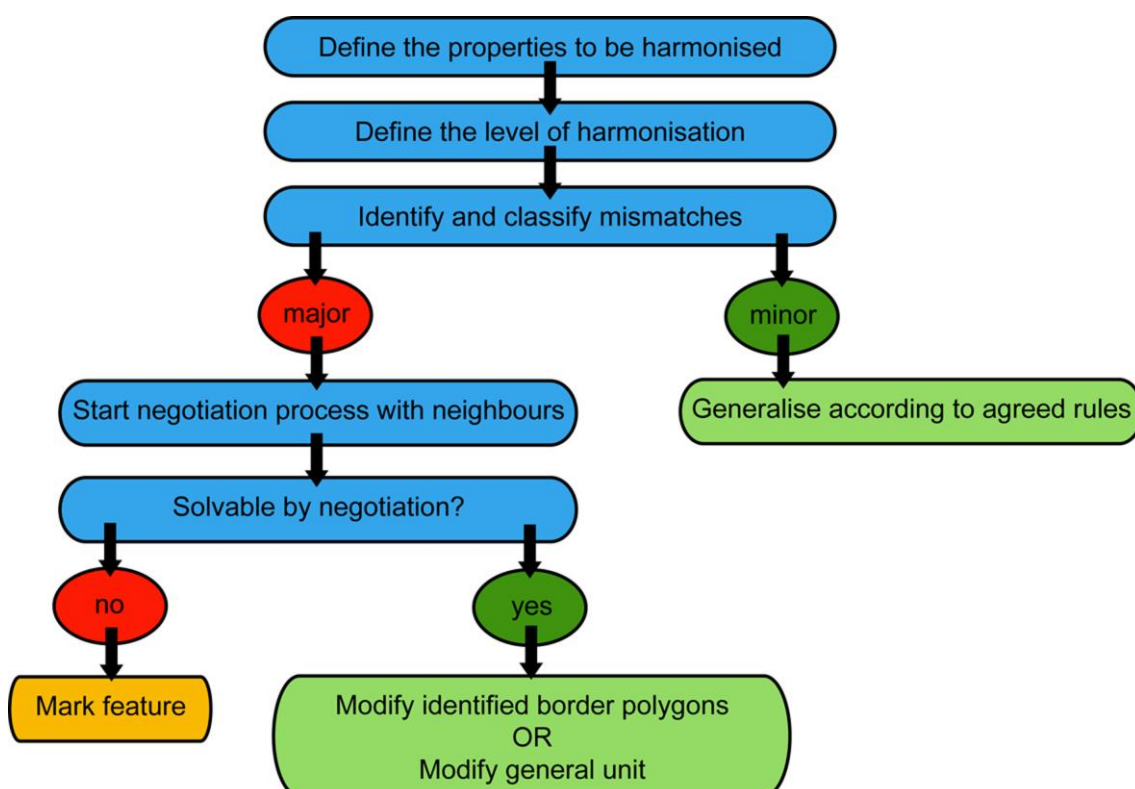


Figure 3-1: Schema developed by WP3 showing the necessary steps of the process of harmonisation.

Step 1: Define the properties to be harmonised

The first step of every harmonisation process is the definition of those properties that need to be harmonised. This includes for example the question of which layers, (surface or bedrock geology or both) and which properties (lithology, age, lithostratigraphy, and/or geological environment) are to be harmonised. For 1G-E it was decided to harmonise the lithology and the age of both the surface and bedrock layers as far as possible and to restrict the

harmonisation to the border regions (not to extend to all geologic units) due to the short time scale available in which to progress this work.

Step 2: Define the level of harmonisation

The second action in the harmonisation process is the definition of the level of harmonisation. In this step it is decided to what extent the semantic and geometric misfits are to be resolved. It could, for example, be agreed that a preferred stratigraphic level (e.g. stage level) should be used. Alternatively a resolution could be defined, so that polygons which are smaller than a particular size are not harmonised.

- For 1 G-E a pragmatic approach was adopted: Only the predominant lithology was harmonised (the subordinate ones may differ). In this way the colours in the portrayal conform to each other.
- For semantic harmonisation issues, due to different hierarchy levels of the terms, it was decided to individually “go one level up”, i.e. to change the more detailed term to its broader concept.
- For geometric displacements that are smaller than ca. 500m the polygons may be snapped to fit each other across the boundary.
- Mismatches that are not visible at a scale of 1:100'000, i.e. polygons that are smaller than ca. 2.5km in diameter do not need correction at all.

In addition it was decided to first harmonise the semantic issues and after that to progress geometric harmonisation. This is because many minor geometric mismatches are resolved when semantic harmonisation is previously carried out. In addition geometric harmonisation usually creates further changes in the data set.

Step 3: Identify and classify mismatches

After establishing these general guidelines for the harmonisation, the mismatches have to be identified and classified. In 1G-E this was mainly done by ‘hand’, i.e. by comparison of the adjacent border polygons. A possible way to identify and classify the harmonisation issues is the usage of a “mismatch matrix” (fig. 3-2).

The first four columns identify the particular polygon: a sequence number; the regions where the issue is located; and the FIDs, these are the unique identification numbers given to the polygon by the two Geological Surveys either side of the border, in this case the BGR (Federal Institute for Geosciences and Natural Resources) and the PGI (Polish Geological Institute).

In the next two columns it is stated, whether there are topological or geometrical mismatches (yes – orange; no - green).

The semantic harmonisation issues are examined in the next five columns. Since it is possible to encode up to five different lithologies (predominant and subordinate) in 1GE, these are designed to compare each of these lithologies separately.

In the last column the petrological order of the lithology terms can be stated. It is possible, that two countries describe the lithology with the same terms, but in a different order. If this is the case, the comparison of the different lithologies might not be significant and the option ‘dpo’ (different petrographical order, yellow) should be entered.

To compare the lithologies and to classify their differences the following categories prove to be useful:

IDENTIFICATION MATRIX FOR BILATERAL HARMONISATION

BGR / PGI

No.	Region	BGR [FID]	PGI [FID]	topologic issue	geometric issue	litho_1 (predominant)	litho_2 (subordinate)	litho_3 (subordinate)	litho_4 (subordinate)	litho_5 (subordinate)	Petrographic order
1	Swinemünde / Świnoujście	909	87	y	y	ic	ic	ic	ic	ic	
		985	87	n	n	cc	cc	cc	cc	cc	
2	Pomellen / Kolbaskowo	1752	77	y	y	cc	ne	ne	ne	ne	
		1781	77	n	y	sc	pc	ne	ne	ne	
		1781	94	y	y	ic	ne	ne	ic	ic	
		2054	94	n	y	sc	sc	cc	ic	ic	
		2177	94	n	y	ic	ne	ne	ic	ic	
		2390	76	y	n	ic	ic	ne	ne	ne	
		2390	97	y	y	sc	sc	sc	ne	ne	dpo
		2390	58	y	y	ic	sc	sc	ne	ne	dpo

Geometric/Topologic harmonisation

y yes: there is a harmonisation issue, either topological or geometrical

n no: the polygons match each other geometrically or topologically

Semantic harmonisation

ic identical concept

pc parent child

sc similar concept

cc contrary concept

ne no entry, at least in one polygon

dpo the same concepts were used, but in a different petrographical order

Figure 3-2: Mismatch matrix for the identification and classification of geometric and semantic harmonisation issues at polygons adjacent to the boundary.

Identical concept: When both countries used the same concept for the description of the geologic unit no harmonisation is necessary.

Parent child: The terms for the description of the lithology differ only in the hierarchy level, i.e. one term is the parent concept of the other e.g. monzogranite and granite (fig. 3-3).

Similar concept: Similar concepts are defined in two ways. In the first case both terms share the same parent concept, e.g. granite and tonalite – both terms are subcategories of granitoids. In the second case one term is a broader concept of the other by two hierarchy levels e.g. quartz_diorite and dioritoid (fig. 3-3).

Contrary concept: A term is contrary if it is not 'identical', 'parent child', or 'similar'. The transition between similar and contrary concepts is transitional and the division between them can be defined differently depending on the degree of harmonisation required. For example for a high level of harmonisation all sub-classes in fig 3-3 might be combined into the parent term of phaneritic igneous rock.

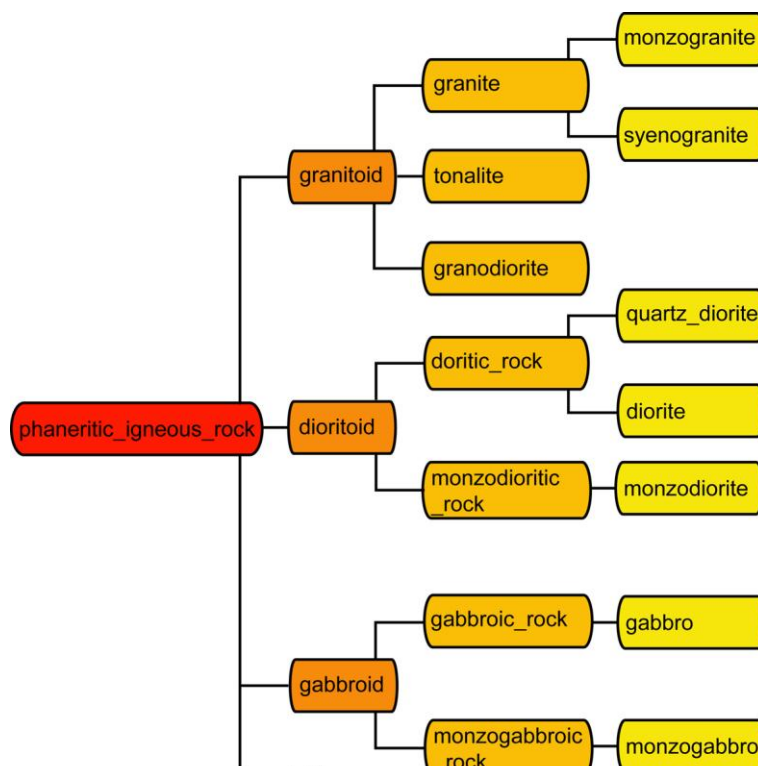


Figure 3-3: Extract from the hierarchy chart of Igneous material, showing the relations of the terms to each other.

Step 4: Harmonisation of minor mismatches: Generalise according to agreed rules

If the identified mismatches are minor, e.g. two lithological concepts, that differ only in the hierarchy level or a geometric displacement that does not exceed 500m, then these issues can be resolved according to the agreed rules in step 2 (Define level of harmonisation). For a semantic issue, which was characterised to be a 'parent child', the term with the lower hierarchy level would be changed to the parent term ("Generalise according to agreed rules", fig. 3-1).

Step 5: Harmonisation of major mismatches: start negotiation process with neighbours

If the harmonisation issues are major, and therefore cannot be easily resolved using the agreed guidelines, it is absolutely essential to coordinate and cooperate bilaterally. To solve the harmonisation issues it is necessary for the regional geologists of both countries to check the background data for accuracy; research, whether new data is available; reflect, whether different concepts or different geological interpretations were used to describe the lithology etc. The aim of this negotiation process should always be to find a solution that is scientifically correct and conforms to both datasets. To harmonise these issues, it may be necessary to redraw particular polygons, to redefine some lithological or stratigraphical units or to generalise the geology of one (or both) countries. If the negotiation process is successful, then the agreed modifications should be applied to either only the border polygons or generally to all polygons of that particular type. If the mismatch could not be resolved by negotiations, for example if further field work is required, the polygon should be marked with this information.

3.2 Technical Solutions

The major result for the end users of the 1G-E project is an assemblage of geological maps across Europe. The maps provided by the partner's different mapping services are characterised by a harmonised vocabulary and database structure giving the first steps towards a harmonisation process for the semantics and the geometry of the mapped features.

The Geological Data Harmonisation Workshop in Bled, Slovenia (17.-19.05.2010) highlighted that it would be desirable if the discovery procedure for map disharmony between countries could be automated in future. Development and implementation of querying tools (sql like) into the geoportal could increase the automatic identification of potential mismatches across national borders. However, unlike Geographic Information Systems (GIS), web services do not allow the generation of new topology between data layers, such as those from two neighbouring countries, and spatial querying on the resulting overlays. The potential for automatic harmonisation using web services is therefore very limited at present. Neighbouring countries could however load their data into a GIS and carry out harmonisation analysis offline, prior to uploading data to 1G-E.

The partners of the 1G-E project are already providing Web Map Services (WMS) and Web Feature Services (WFS) using different software including Mapserver, Geoserver, and ArcGIS Server which permit the display and querying of the map databases. A WMS is a standard protocol for serving images of maps generated by a map server using data from a GIS database. The response to a request is one or more geo-registered map images (returned as JPEG, PNG, etc) that can be displayed in a browser application. The interface also supports the ability to specify whether the returned images should be transparent so that layers from multiple servers can be visualised when overlain (www.opengeospatial.org). The WFS specification defines interfaces for describing data manipulation operations of geographic features. Data manipulation operations include the ability to: 'Get' or 'Query' features based on spatial and non-spatial constraints and editing like inserting, deleting and updating a feature instance.

A basic Web Feature Service allowing querying and retrieval of features has already been implemented by 1G-E WP6. This enables the discovery of disharmonies between the mapped features of the participating countries, but the editing process has to be made in the original dataset by each data provider using their own GIS and database software. This limits the speed and ease of the harmonization processes.

The development of a transactional Web Feature Service (WFS-T) allowing insertion, deletion, and updating of features directly on the geoportal would enable the data provider to make more rapid progress towards the harmonisation of their data with their neighbouring countries. The technical implementation of a WFS-T is more problematic depending on the map server software used. For instance, Geoserver and ArcGIS Server support WFS-T but Mapserver 5.6 does not directly. Interfacing TinyOWS and Mapserver allows the option of live editing with a WFS-T to the server, Mapserver taking care of the map rendering and displaying and TinyOWS the transactional processes. The main goals of TinyOWS are performance and respect of standards such as OGC and ISO. The software is designed to improve significantly the capacity and speed of WFS services, it would thus be a good extension to the service that most of the 1G-E partners have already set up.

There are however significant data management issues that would need to be addressed if editing was to be carried out using the web service. Commonly a data provider's internal

database is not structured in the same way as the data used for interoperability services such as 1G-E, and the internal data is mapped to the structure used for interoperability such as GeoSciML. This mapping may be carried out dynamically or it may be carried out offline, creating a replica database with the structure required for interoperability which is updated from the internal database periodically. If web services are used for editing then this mapping process needs to be reversed so that changes made in the interoperability data are cascaded back to the internal database of the data provider. This will not always be possible depending on the nature of the mapping, for example if generalisation is carried out.

4. Harmonisation Issues across Europe and their Solutions

4.1 Harmonisation Examples carried out in 1G-E

This section highlights some harmonisation issues and their individual solution, which were addressed during the 1G-E project.

4.1.1 The Netherlands – Germany

The harmonisation issue is located in the region around Meppen/Ems and concerns river deposits. The petrographical description of these sediments is the same in the original maps of both The Netherlands and Germany: the sediments are composed of silt, sand, gravel and peat. Due to the differing interpretations of these deposits and differing degrees of generalisation semantic and geometric harmonisation issues occur alongside the national boundary (fig. 4-1).



Fig 4-1: Screenshot showing the lithology layer with the semantic and geometric harmonisation issues (indicated by the arrows) alongside the Dutch-German boundary in the region of Meppen/Ems. Note the gaps (white areas) between the datasets which originate from the use of different geographic bases.

Since numerous harmonisation issues like this occur along the Dutch-German boundary a brief meeting of TNO and BGR was held (on 11.08.2010 at the BGR) to discuss possible solutions. This meeting was very successful and nearly all harmonisation issues could be solved.

Figure 4-1 shows that the river deposits are described in The Netherlands as predominant silt with subordinate sand and peat. On the German side these river deposits were described like the surrounding glacial deposits as predominant sand and gravel. At the meeting mentioned above it was decided to set all polygons of this river setting to predominant silt with subordinate sand, gravel and peat. Figure 4-2 shows that due to this change nearly all semantic and geometric harmonisation issues in this region could be resolved.



Fig 4-2: Screenshot showing the lithology layer after solving the harmonisation issues alongside the Dutch-German boundary in the region of Meppen/Ems. Note that no gaps can be seen since both datasets were mapped to the common geographic base Eurogeographics. The shape of the peat polygons as well as their termination at the national boundary originates from the mining of this formation.

4.1.2 Slovenia – Italy

This harmonisation issue is located near Gorizia (Slovenia). On the Italian side the main lithology is described as predominant diamicton with subordinate clay, silt, sand and gravel, whereas on the Slovenian side the same lithological unit is described as predominant clastic sediment with subordinate conglomerate (figure 4-3). Since the sediments are deltaic, alluvial and fluvial deposits, the term diamicton is not correct, because it describes glacial deposits and moraine material. Therefore the predominant lithology was changed to Clastic sediment on the Italian side (figure 4-4).

In addition to this semantic harmonisation issue numerous small geometric displacements are present (figure 4-4). These could not be solved due to their complexity and the short time available.

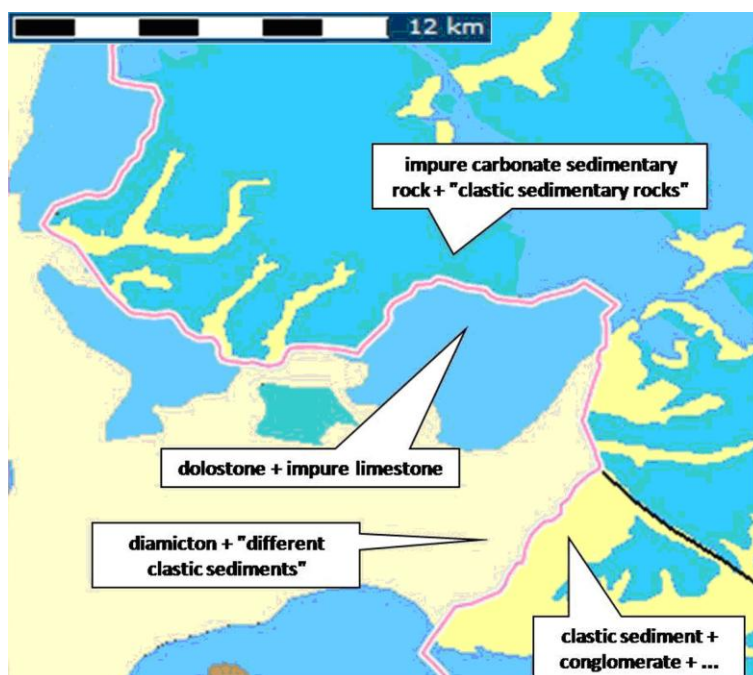


Fig 4-3: Screenshot showing the Slovenian-Italian border region and the semantic and geometric lithological harmonisation issues. These are mainly derived from the different description of the predominant lithology.

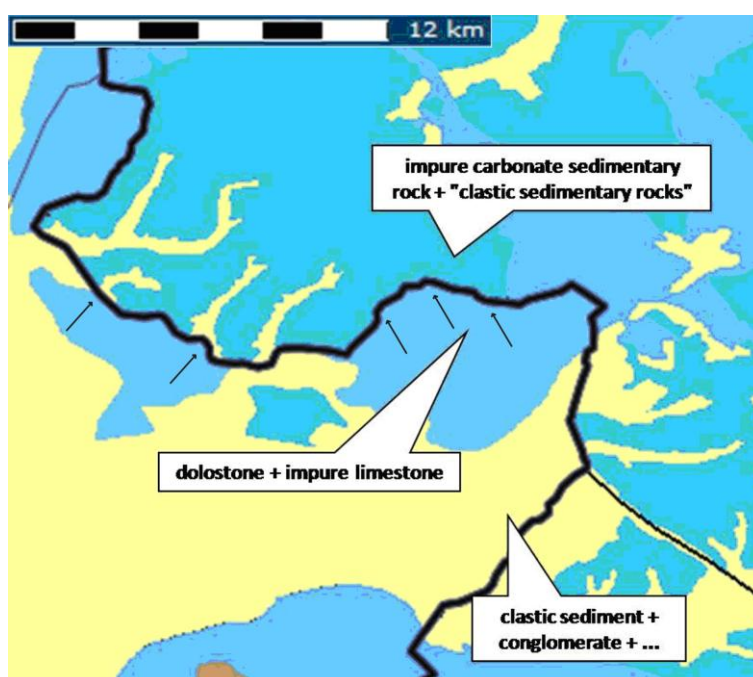


Fig 4-4: Screenshot showing the Slovenian-Italian border region after the harmonisation process. The main semantic harmonisation issues regarding the predominant lithology could be solved; the geometric harmonisation issues (indicated by the black arrows) still remain.

4.1.3 Czech Republic – Germany

Germany used a 1:1 000 000 scale national map to implement their data for the 1G-E project, whereas the Czech Republic used a more detailed national map with a scale of 1:500 000. This difference in the scales of the original maps led to many geometric and semantic harmonisation issues along the national boundary. One example of such a harmonisation issue is located in the “Erzgebirge”. Due to the more detailed background map, the lithology on the Czech side distinguishes between phyllite, mica schist, quartzite, shale and granite. The German side is much less detailed: there the lithology is limited to phyllite, shale and granite. Therefore the polygons of the quartzite and mica schist do not continue in Germany (fig. 4-5).

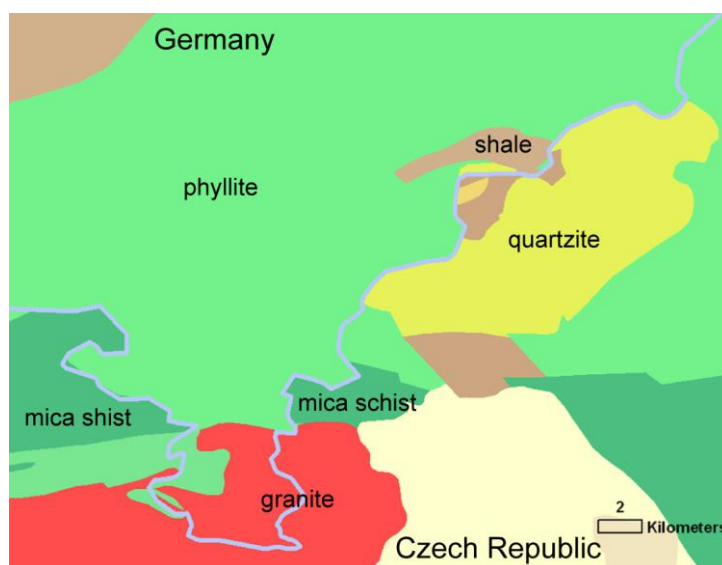


Fig 4-5: Screenshot showing the Slovenian-Italian border region and the semantic and geometric lithological harmonisation issues. These are mainly derived from the different description of the predominant lithology.

During the harmonisation process a second German geologic map with a higher scale of 1:200 000 was consulted, which verified the existence of quartzite and mica schist. Therefore three additional polygons were added on the German side of the boundary. Not all geometric harmonisation issues could be solved by this action; further negotiations and/or fieldwork would be required to finish the harmonisation (figure 4-6).

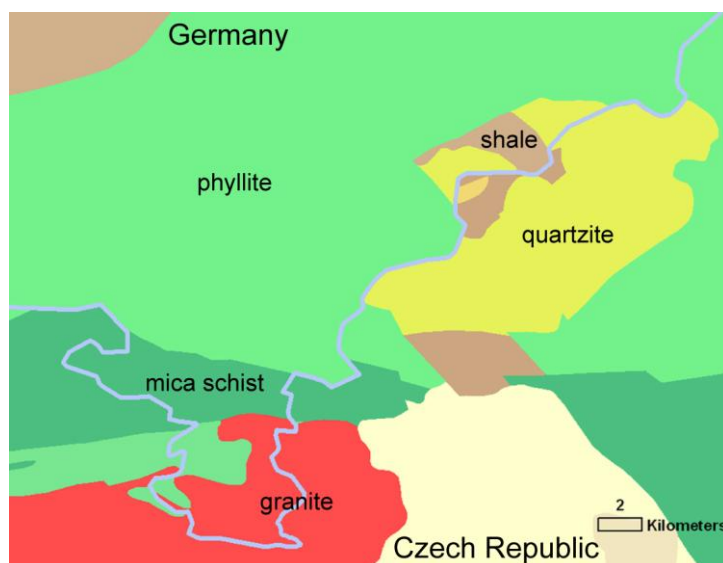


Fig 4-6: Screenshot showing the Slovenian-Italian border region after the harmonisation process. The main semantic harmonisation issues regarding the predominant lithology could be solved; the geometric harmonisation issues (indicated by the black arrows) still remain.

4.1.4 Belgium – Luxembourg

Along the northern part of the Belgian-Luxembourgian national boundary no harmonisation issues occur. In the southern part, in the region around Arlon, several semantic harmonisation issues regarding the stratigraphy are located. These are derived from the use of differing levels of detail for the definition of the ages: Belgium uses the Epoch level, i.e. Late/Upper Triassic and Early/Lower Jurassic, to characterise the age of the geological units. Luxembourg on the contrary uses the Stage level, i.e. Induan, Anisian, Ladinian, Hettangian, Pliensbachian and Toarcian for the description of their geological units (figure 4-7).

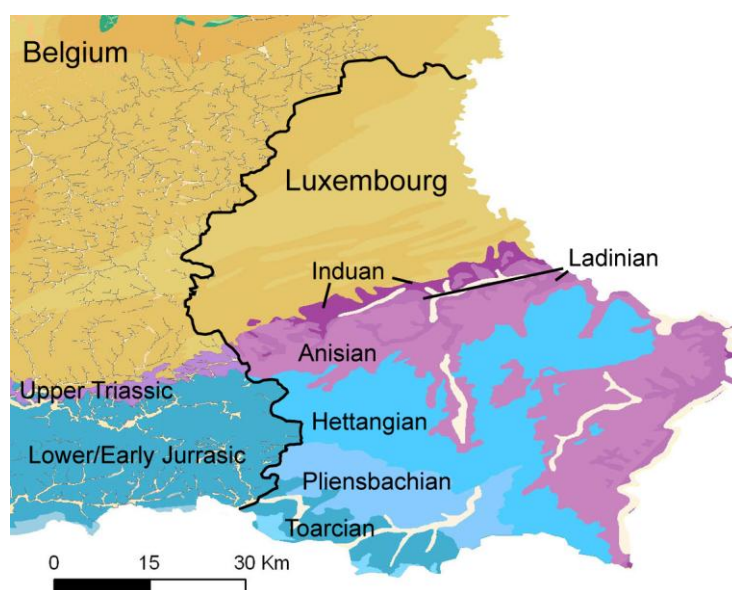


Fig 4-7: Screenshot showing the semantic harmonisation issues of the stratigraphy along the Belgian-Luxembourgian border region. These are mainly due to the use of different levels of detail and can be solved by changing the term with the lower hierarchy level to its parent term.

Since the Stages Hettangian, Pliensbachian and Toarcian are all child concepts of the Epoch Early/Lower Jurassic, this harmonisation issue can be classified as minor and the harmonisation is carried out by generalising according to the agreed rule. In this case, this means changing the term with the lower hierarchy level (i.e. the Hettangian, Pliensbachian and Toarcian) to their parent term, i.e. to Early/Lower Jurassic (fig. 4-8).

The second harmonisation issue needs more bilateral cooperation to be solved. Belgium describes the respective geological unit to be of Upper Triassic age. Luxembourg describes the same geological unit to be of Ladinian age, which corresponds to Middle Triassic age of the IUGS-ICS Stratigraphic Chart (2009). This originates from the use of national concepts: Luxembourg uses the traditional concept of the “German Triassic”, which is subdivided into “Buntsandstein”, “Muschelkalk” und “Keuper”. The age transitions of these subdivisions do not conform to those of the IUGS-ICS Stratigraphic Chart. The age, which divides the “Muschelkalk” and the “Keuper” lies within the Ladinian of the Stratigraphic Chart. The respective geological unit is characterised as “Keuper” in the original lithostratigraphic map of Luxembourg, therefore it can be renamed to Upper Triassic (fig. 4-8).

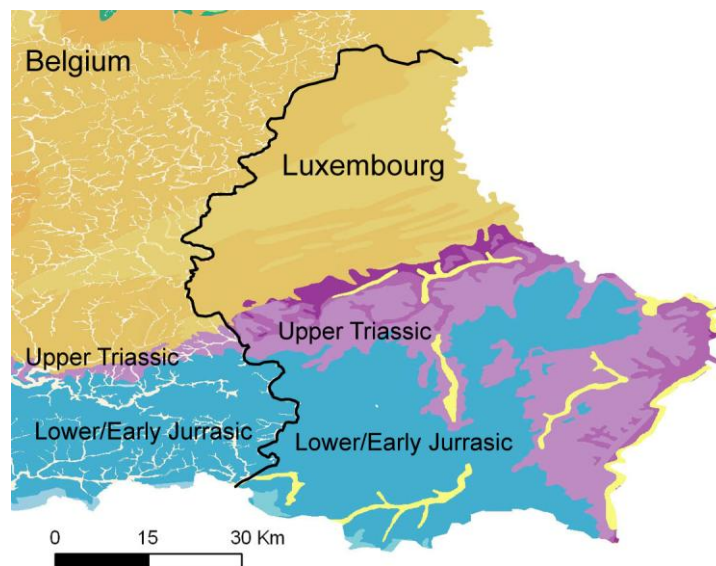


Fig 4-8: Screenshot showing the stratigraphy along the Belgian-Luxembourgian border region after the harmonisation. Note that the harmonisation was only applied for those polygons with a direct contact to the national boundary, which was one of the harmonisation agreements of the 1G-E project (see section 3.1).

4.1.5 Germany – France

The harmonisation issue is located in the cross-border region between Saarland (Germany) and Metz (France). The issue is particularly complex, because it includes both semantic and geometric problems of the Stratigraphy and is related to the usage of different traditional concepts for the Triassic strata in both countries (fig. 4-9).

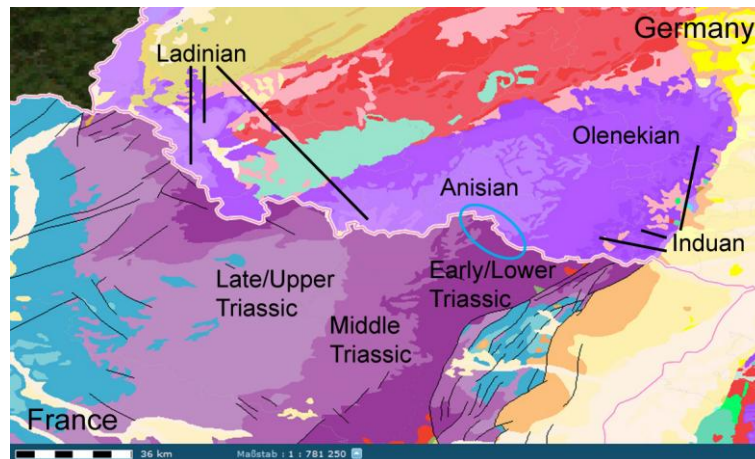


Fig 4-9: Screenshot showing the Stratigraphy and the semantic and geometric harmonisation issues along the German-French boundary (see also fig. 2-2 and 2-6), which are derived mainly by the use of different stratigraphic levels and traditional concepts.

The main semantic problem is the use of different degrees of detail for the Triassic ages: France uses mainly the Epoch level, i.e. Early/Lower Triassic – Middle Triassic – Late/Upper Triassic; whereas Germany works with the Stage level, i.e. Induan – Olenekian – Anisian – Ladinian. In addition, the geometry of the strata shows a displacement of several km (marked with the blue ellipse in fig. 4-9).

The lithology layer of the 1G-E map shows that there are only minor harmonisation issues and that the considerable geometric problem of the Triassic stratigraphy is not reflected in the lithology (fig. 4-10). The main semantic lithological difference is the description of the geological units of the upper and lower “Muschelkalk”: France describes these units as impure carbonate sedimentary rock, whereas Germany classifies them as limestone.

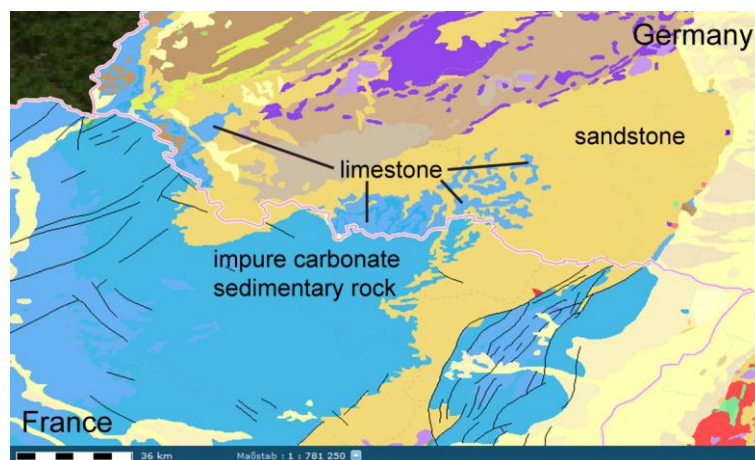


Fig 4-10: Screenshot showing the Lithology and the minor semantic harmonisation issues along the German-French boundary.

The first step towards stratigraphic harmonisation is the use of a common stratigraphic level. For this purpose the German Induan and Olenekian, and Anisian and Ladinian units are

combined to Early/Lower Triassic and Middle Triassic, respectively. Due to this semantic correction some geometric misfits are also resolved, but the major displacement described above (blue ellipse in figure 4-9) remains.

Like the harmonisation issue between Belgium and Luxembourg, this major geometric harmonisation issue is related to the use of the traditional concept of the “German Triassic”. The geologic unit described as sandstone (figure 4-10) shows, that no semantic harmonisation issue is present in the lithology. This unit was defined to be of Early/Lower Triassic age by France. In the lithostratigraphical map of Germany this unit is characterised to be a unit of the “Upper Buntsandstein”. The age range of the “Buntsandstein” is translated to Induan towards Anisian of the IUGS-ICS Stratigraphic Chart, the respective geological unit can be redefined to Early/Lower Triassic. By changing the ages on the German side of the boundary, the stratigraphic harmonisation issues can be resolved (fig 4-11).

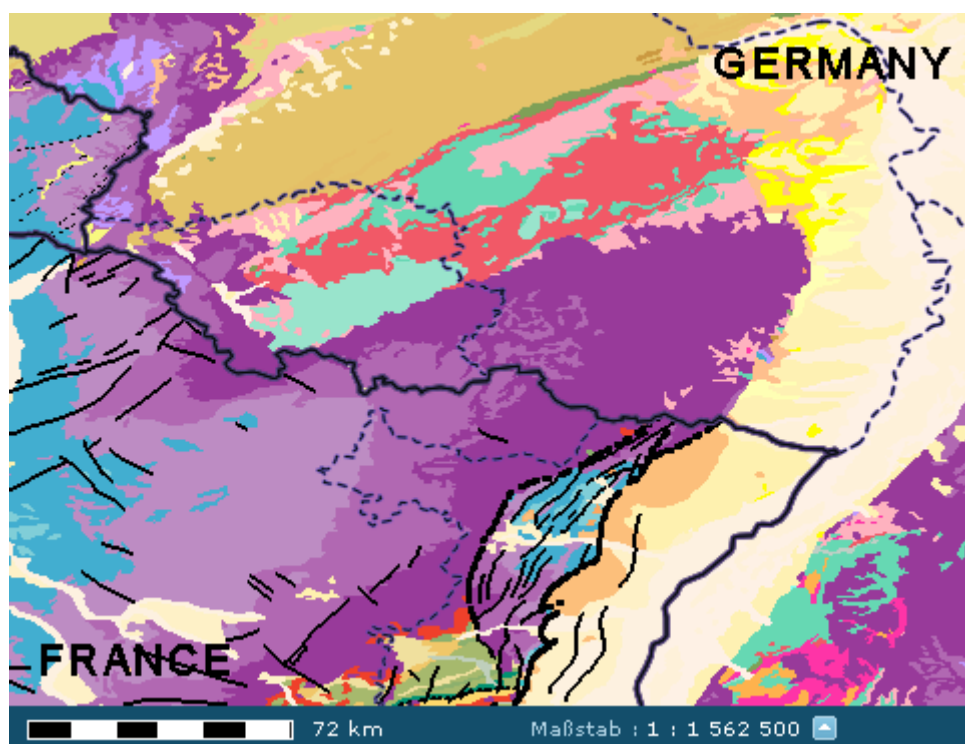


Fig 4-11: Screenshot showing the stratigraphy along the German-French boundary after the harmonisation process. The semantic and geometric harmonisation issues could be solved by defining a common level for the stratigraphy and the translation of national concepts to the 1G-E vocabulary.

4.1.6 Italy – France

The French-Italian boundary is located entirely in the Western Alps. Due to the complexity and heterogeneity of the geology in this region there are many different approaches on its mapping and interpretation. All countries in which the Alps are located developed different geological concepts for their geology and formation. These facts (in addition to the e.g. differences in the geographical base, the use of outdated original maps etc.) led to numerous severe harmonisation issues alongside the French-Italian boundary (fig. 4-12).

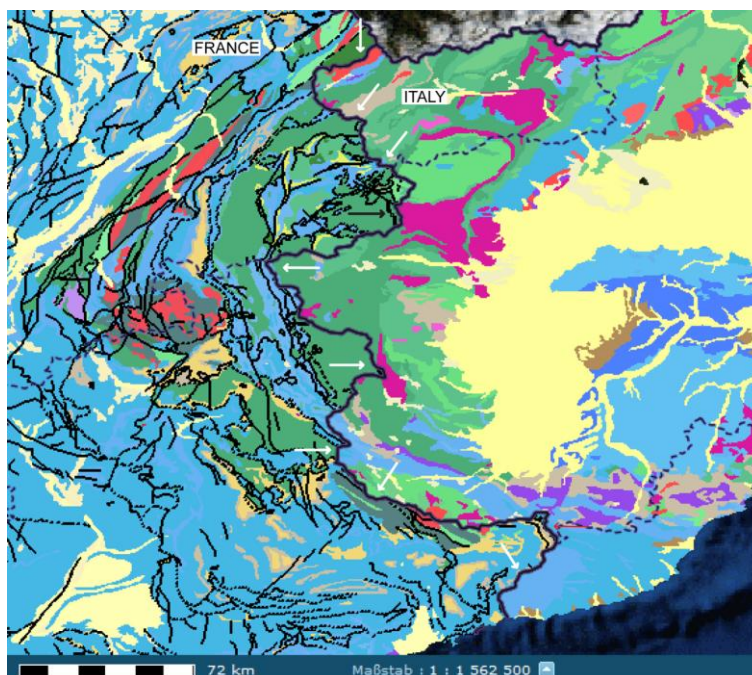


Fig 4-12: Screenshot showing the lithology and the numerous harmonisation issues (indicated by the white arrows) alongside the French-Italian boundary.

The harmonisation of the maps of France and Italy could not be accomplished during 1G-E due to the complexity of the geology. To solve these issues a specific project, the Western Alps geological harmonisation project (preliminary title), will be carried out by the BRGM (Bureau de Recherches Géologiques et Minières, France) and the ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale, Italy). To harmonise the data all recent cartographic products (both geological and topographical) will be assembled and exchanged between the countries. Based on this a working group (regional geologists and GIS experts from both geological surveys) will discuss the issues, propose possible solutions, ascertain whether field work is necessary, and redraw a common harmonised map (using the 1G-E vocabulary).

4.2 Harmonisation Examples carried out in other projects

4.2.1 France – Spain: Geological map of the Pyrenees at a 1:400'000 scale

The project “Geological map of the Pyrenees at a 1:400'000 scale” was carried out during 2006 and 2007 by the Geological Surveys of France (BRGM) and Spain (IGME) and published in 2008. Both Surveys financed the project with their own mapping programme funds.

The aim of the project was the development of a common, coherent data set of the Pyrenees and the harmonisation of this French-Spanish border region. The map was designed to be usable for educational purposes and understandable by tourists visiting the area as well as geologists. One of the greatest achievements of the project is the harmonised map showing a seamless Pyrenean geology across the border. The dataset is available in both Spanish and French. In addition to the geology, the map shows the topographical contours, roads, cities, villages, rivers and lakes.

The development process of the geological map of the Pyrenees involved 2 years of comparing the national data sets, agreeing on the same geographical reference system, bilateral discussions of the geological concepts and interpretations, agreeing on a common semantic vocabulary and the redrawing/changing of polygons. This work was done by the head of the project, Philippe Rossi (BRGM), and a team of 5 geologists (2 French geologists from BGRM and Nancy School of Mines, and 3 Spanish geologists from IGME, all specialists in Pyrenean geology) and 2 geomatics engineers (one from BGRM, one from IGME). Most of the cooperative discussions and modifications of the data sets took place during two workshops in Orleans and Madrid, but lots of communication was also needed beforehand and afterwards via email. To complete the harmonised data set, some areas of the national data had to be completely redrawn; others could be kept as they were.

The initial situation of the Pyrenean data sets is shown in fig. 4-13. Neither the semantic, nor the geometry fits across the border.

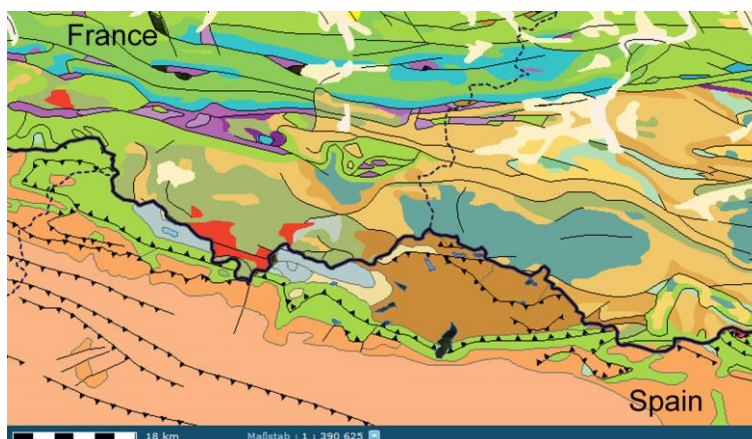


Fig 4-13: Screenshot showing the semantic and geometric misfits across the Spanish-French border in the Pyrenean region.

One reason for these huge misfits might be that the available data sets were not mapped in coordination by the two countries, so that different geological interpretations and concepts were used. In addition the resolution of the French map was higher than that of the Spanish, which always creates geometrical problems.

Figure 4-14 shows the entire harmonised geological map of the Pyrenees, which was developed in that project and a cut-out showing the same area as in figure 4-14.

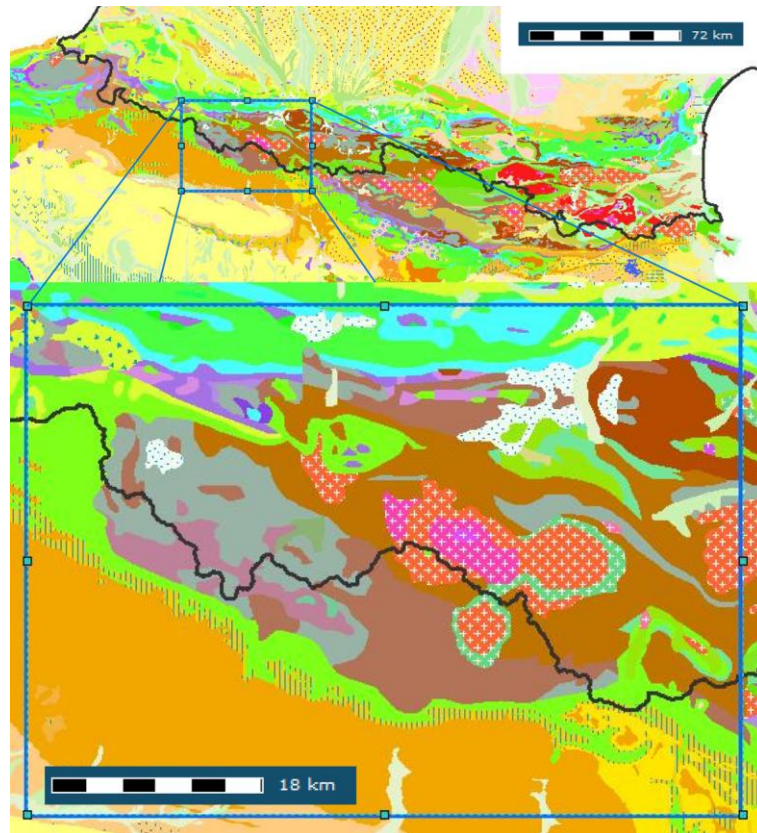


Fig 4-14: Entire harmonised geological map of the Pyrenees at a 1:400'000 scale plus a detail picture highlighting the same area as shown in figure 4-13.

This project shows that harmonisation of the entire datasets of two adjacent countries is a major exercise, that takes a lot of work and time. Such an endeavour cannot realistically be done in a project like 1G-E, but needs additional projects similar to that described within this section.

5. Advantages and Disadvantages of Interoperability and Harmonisation

Advantages

The advantages of making digital spatial data interoperable differ depending on the level of interoperability that is implemented. For schematic interoperability, where there is harmonised data structure but not necessarily harmonised data content, the main advantage is that data using organisations can receive data from different providers in a standard form allowing standardised processing including the development of standardised software. Third party vendors may develop software around such a standard structure providing advantages even to organisations that only use data from one providing organisation.

Extending harmonisation to the data content, semantic harmonisation, provides further benefits. It enables the sharing and exchange of scientific knowledge and data beyond the limits of one data provider or one country to give genuine interoperability. In turn this accelerates the development and deployment of international interchange standards for geological data. A semantically harmonised data set can be queried in a consistent way by a non-specialist user without the need for an expert to relate the different concepts used by different data providers.

Extending interoperability further to include geometric harmonisation, as was done in 1GE, leads to a seamless, harmonised and thus coherent spatial data set, with a common vocabulary and portrayal, which simplifies usage and increases understanding for non-specialists.

Disadvantages

The major disadvantage of harmonisation is the loss of information, because generalisation commonly reduces the scientific resolution. Thus, it is essential to make sure that the original national data sets are kept as the primary data sources, which are used to generate the harmonised data sets. There are clearly data management issues involved with this in deciding what information from the harmonisation process is added in the primary data set, for example adjusted geometry at borders, and what is not, for example simplified stratigraphy. In the future the use of ontological mapping between different concepts may allow more automatic semantic harmonisation and thus reduce the problem of a mismatch between the primary and harmonised data sets.

When considering the degree of harmonisation to be carried out it is very important to consider the use case. For some use cases, such as that of 1GE, the primary objective is spatial and semantic integration of multiple data sets, and loss of scientific resolution is acceptable in achieving this. For other use cases, such as a Geological Survey providing information to a customer for a site specific survey, there should be no loss of scientific resolution and interoperability with other data providers is not required, so in this case schematic interoperability is all that is needed.

If harmonisation is restricted to the border regions (as it was done in 1G-E) then many of the harmonisation problems are simply dislocated inland. If only those polygons adjacent to the border are modified then they may differ from polygons of the same geologic unit located further away from the border. Therefore the data set seems harmonised, but in fact is not. This implies that harmonisation should, ideally, be applied to complete data sets.

6. Summary and Recommendations

Summary

The harmonisation of at least 20 different data sets with entirely different standards, semantics, portrayals and scales is not an easy endeavour. However, harmonisation is possible and it is an important task. Work package 3 of OneGeology-Europe had the task of “Making progress towards harmonisation” and it succeeded.

The 20 1G-E member countries share around 11,700 km of national boundaries between them. It is obvious that not all occurring discrepancies at these political boundaries could be solved within the project timeframe. Thus, to complete the task of making progress towards harmonisation a representative number of cross-border regions were selected, where solutions to harmonisation issues were developed.

The following neighbouring countries harmonised the surface geology of parts of their national boundaries:

- Sweden – Finland – Norway (in addition the bedrock geology was also harmonised.)
- United Kingdom - Ireland
- Germany - Denmark
- Germany – Netherlands
- Germany – Poland – Czech Republic
- Czech Republic – Slovakia
- Hungary – Slovenia (only the age layer)
- Slovenia – Italy (only the lithology layer)
- Belgium – Luxembourg – France – Germany
- France – Spain
- Spain – Portugal

Harmonisation issues that were not solved during the 1G-E project, were just identified and marked as such. Most of these unsolved issues are especially complex and may require further field work in cooperation between the countries involved to reach a suitable conclusion.

However, the identification of the differences in the mapping of two adjacent countries is a significant first step towards harmonisation, a base for the actual harmonisation process and thus an excellent result of the 1G-E project.

Recommendations

This report concludes with a number of recommendations:

1. Before beginning any harmonisation process it is important to identify the specific user needs relevant to the project, as a base for defining the suitable level of harmonisation. Harmonisation should add value and be no more than is necessary!
2. Standard guidelines need to be agreed and defined, including a conceptual harmonisation process, served by technical means (e.g. transformation services). This should comprise a standardised workflow (a routine course of actions) for harmonisation (as described in section 3.1), lay down the suitable level of harmonisation defined by the user needs (see recommendation 1), and clearly

defined rules, whose usage are mandatory for all participants so that a consistent approach to the problems and questions envisaged is ensured.

3. Many of the problems encountered in the WP 3 harmonisation process were due to the large range of scales of the input data. While this could be avoided by defining a close input scale range, if it is not possible (and when one is dealing with pre-existing national data it may not be) then it is recommended to define two or three target scale ranges, e.g. 1 : 250 000 or 1:1 million. The difference of detail and resolution in these scale ranges is enormous.
4. Absolutely essential is the agreement and adoption of a standard semantic base (vocabulary, thesaurus, term dictionary) and data model. Without that no semantic harmonisation issue can be achieved.
5. Equally essential as a base for any successful geometric harmonisation is the use or adaptation of the same geographic base as it solves topology and coordinate reference system issues.
6. Using a systematic approach, e.g. cross-border correlation tables, is useful means to identify and solve the issues of semantic discrepancies.
7. Communication and negotiation is an integral part of the harmonisation process. Cross-border harmonisation means compromises and those are impossible without communication across political boundaries. Although this may be perceived by some as superfluous and intangible effort, good communication and interpersonal contact not only enables harmonisation, but also helps cross-boundary understanding of common issues.
8. Technically, the development of an automatic “mismatch discovery” procedure (at political boundaries) would very much help to rapidly identify and classify harmonisation issues at these boundaries. This development is proposed as a worthwhile research and development project.
9. Similarly, the initiation of a cross-boundary test bed that develops and tests technical solutions that allows live editing of distributed spatial data served by WFS (see section 3.3) is recommended.
10. In conjunction with recommendations 8 and 9, the development of a technical harmonisation tool would significantly simplify the process of harmonisation. At present this does not appear possible with web services technology and so to address this, a research project with the aim of developing such a tool is recommended.
11. Finally, for benefit of all the stakeholders of OneGeology-Europe, at local, national and European levels, it is recommended that full advantage should be taken of the considerable effort devoted by the project to the development of the first European basic geological data specification and a harmonised European dataset. Thus we recommend that a follow-up project aiming to resolve the remaining harmonisation issues is specified and supported by the EC and the geological surveys of Europe.

7. Abbreviations

1G-E	OneGeology-Europe
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)
BRGM	Bureau de Recherche Géologiques et Minières
CGI	Commission for the Management and Application of Geoscience Information
CGMW	Commission for the Management and Application of Geoscience Information
D3.1	OneGeology-Europe WP3 Data Specification
EC	European Commission
EU INSPIRE Directive (2007/2/EC)	Directive of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) to support Community environmental policies, and policies or activities which may have an impact on the environment.
EC Water Directive	Directive of the European Parliament and of the Council of 22 nd September 2006 to protect soils across the EU.
EC Soil Directive	Directive of the European Parliament and of the Council (98/83/EC) to protect the health of the consumers in the EU and to make sure the water is wholesome and clean.
EU	European Union
GeoSciML	Geo Science Markup Language (a GML Application Schema that can be used to transfer information about Geology)
GIS	Geographic Information System
GML	Geography Markup Language (an XML grammar defined by the Open Geospatial Consortium (OGC) to express geographical features)
ID	identification number
IGME	Instituto Geológico y Minero de España
INSPIRE	INfrastructure for SPatial Information in Europe IUGS International Union of Geological Sciences (non-governmental organisation)
ISPRA	Istituto Superiore per la Protezione e la Ricerca Ambientale
IUGS-CGI	Data Model Collaboration Working Group
OGC	Open Geospatial Consortium
SDI	Spatial Data Infrastructure
TinyOWS	Tiny OGC Web Service common
WFS	Web Feature Service
WFS-T	Web Feature Service - Transactional
WMS	Web Map Service

WP	Work Package
WP 1	OneGeology-Europe Work Package on project management
WP 2	OneGeology-Europe Work Package on user cases and best practice in meeting stakeholder needs
WP 3	OneGeology-Europe Work Package on 1:1 million pan-European geological Data Specification, identification and sourcing
WP 4	OneGeology-Europe Work Package on data inventory and multilingual discovery metadata catalogue
WP 5	OneGeology-Europe Work Package on informatics specification, data model, interoperability and standards
WP 6	OneGeology-Europe Work Package on web portal and Registry development and implementation
WP 7	OneGeology-Europe Work Package on access and licensing protocols
WP 8	OneGeology-Europe Work Package on communication, dissemination and awareness
WP 9	OneGeology-Europe Work Package on access to high resolution geological & applied datasets in national & cross border situations
WP 10	OneGeology-Europe Work Package on liaison with related groups and initiatives
XML	Extensible Markup Language

8. References

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