Appendix IV: Evaluation Questionnaires for Molasse Basin pilot case

WP5 - T5.3 Learning from the case studies

Important information

The questionnaire will be based from each case study's lessons learnt report. Please read the selected report thoroughly before completing this questionnaire. The questionnaire should take approximately 2 hours to complete. The questions which are labelled with an (*) are required fields.

Due to the variation in methodological approaches and lessons learnt reports, some questions might be more suited to one case study than others, and some questions may not apply to certain case studies. If a question does not apply to a case study, please explain why.

*Name:	Fabian Jähne-Klingberg
*Organisation:	BGR (federal institute for geosciences and natural resources)
*Date:	07.09.2021
*Case study evaluating *(please highlight)*:	Molasse Basin

Structural Framework

Do you agree with the following statements? :

1. * *In this case study, the structural framework has been successful in making the geology of the area more understandable.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

This statement is understandable for the detailed study areas of the Molasse and NE Bavaria.

However, the domain "South German Block" covers a larger area which is characterized by a slightly differential Permian to Mesozoic history. However, in Fig. 1 only the approximate transitions between the basement units are indicated and not Mesozoic structures like the Kraichgau Basin or sedimentary basins in the foreland of the Bohemian Massif.

2. * *In this case study, the structural framework has been successful in providing a coherent geological context for subsurface applications.*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

The authors describe cases in which geomanifestations oriented to basement structures or fluid pathways in deeper subsurface are masked by thick younger deposits with their own patterns.

3. *In this case study, the structural framework can aid in identifying and/or resolving subsurface management issues? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

The examples presented here considered Structural Framework linkages with geomanifestations at an overview scale. A specific use case related to a usage was not further explained.

4. * In this case study, what issues/barriers do you identify in applying the structural framework methodology? e.g large scale, large amounts of geological data, time consuming etc…*

- Data, data distribution, data uncertainty
- Scale of study
- Overlapping of deformation patterns of different ages and the definition of deformation ages
- The structural framework here presented show the today's structural pattern. For a systematic analysis of relations between specific deformation structures or structural directions to specific geomanifestation time period structural maps could be helpful

5. *In this case study, have you identified any fundamental issues / show stoppers / limitations regarding the application of the structural framework?*

- Data density and degree of GIS-processing of geomanifestation data as well as for structural framework
- Time to carry out a framework which is applicable for multiple-scales.

6. *Do you have any further recommendations / suggestions which would benefit the application of the Structural Framework in this case study?*

As it seems only a structural framework is presented in an overview scale. The comparison to partly small-scale geomanifestations is therefore difficult.

Geomanifestations

Do you agree with the following statements :

7. *In this case study, geomanifestations have been successful as specific expressions that identify ongoing or past geological processes:*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> I find the distinction between areas with a more unique and less unique linkage of geomanifestations with the Structural Framework well described and understandable. However, due to the size of Bavaria and therefore only exemplary treatment of the topic, no complete systematic picture emerges for the viewer.
>
> It would certainly be more impressive if different classes of geomanifestations could be analyzed uniformly over the whole area of Bavaria. Of course, this is closely linked to the data situation and therefore cannot be carried out uniformly everywhere. But seismicity, for example. Is there no congruence at all to the subsurface structures in the Molasse area?

8. *In this case study, geomanifestations have been successful in improving/completing the geological understanding:*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

> As the authors also noted, the structural patterns were already sufficiently known and the here presented geomanifestations should be seen more as additional confirmations of certain structures in the subsurface.

9. *In this case study, was the incorporation of Geomanifestations successful in helping identifying specific/potential management issues in the subsurface? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

This point was not described or discussed in detail.

10. * In this case study, what are the issues/barriers concerning the application of Geomanifestations? e.g large scale, large amounts of geological data, time consuming etc…

- Data density and degree of GIS-processing of geomanifestation data as well as for structural framework
- Time to carry out a systematic analysis of all possible links between structural patterns and geomanifestations.

11. ** In this case study, have you identified any fundamental issues / show stoppers regarding the application of the Geomanifestations?*

- Depending on the particular geomanifestation and geologic cause, other geologic settings may mask the linkage between the geomanifestation and the trigger.
- Before the method is applied on a large scale in a time-intensive manner, predictions of success for the analyses of specific geomanifestations should be made on the basis of exemplary small-scale studies.

No direct show stopper!

12. *Do you have any further recommendations / suggestions which would benefit the application of the Geomanifestations in this case study?*

A list according to which geomanifestations were investigated over the area of Bavaria.

Which ones were excluded and why?

Structural Framework and Geomanifestations integration

Do you agree with the following statements :

13. ** The structural framework model annotated with geomanifestations enhances our understanding of the subsurface*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

It is not always an extension of knowledge but rather a further circumstantial evidence that often additionally confirms already existing theses or studies.

14. *** *The Structural Framework benefits from the incorporation of Geomanifestations into the model*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

This depends on what the structural framework should ultimately represent. A comprehensible scalable representation of today's tectonic pattern of a region or the representation of elements that I somehow manifest today. But that does not necessarily make these structures equally important for characterizing the structural framework.

In the case of NE-Bavaria. The studied geomanifestations highlight structure important for tertiary and recent development, which should also be part of the structural farmework.

15. *** *The Geomanifestations benefit from the context of the Structural Framework*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

The here presented geomanifestations can only be meaningfully explained by understanding the structures implemented in the structural framework.

16. *What barriers prevent both methodologies working (efficiently) together?*

The creation and analysis of a structural framework requires a completely different expertise than the analysis of specific phenomena/geomanifestations.

The challenge is thus to bundle the expertise or replace it with AI.

17. *Overall, has the methodology been applied successfully within the selected area, fulfilling the aims it set out to achieve? Please give a rating out of 10 and offer a brief explication in the box below.*

'The prime aim of GeoConnect³d is the conversion of geological data into subsurface information and critical parameters that can be used for various geo-applications, decision-making and subsurface spatial planning.'

☐ ☐ ☐ ☐ ☐ ☒ ☐ ☐ ☐ ☐
1   2   3   4   5   6   7   8   9   10

The here presented overview study is rather to be seen as a preliminary study for detailed investigations according to specific subsurface applications.

Other Questions

18. *Does the methodology offer additional benefits which were previously unaccounted for?*

Answer : A systematization of the investigation of the subsurface and that across borders according to the same/comparable standards.

19. *Has the methodology opened up new opportunities for further development, exploration or valorisation?*

Answer : The introduction of standards in analysis and standardization will enable evaluation by new computer-aided AI methods in the future of large amounts of data.

Important information

The questionnaire will be based from each case study's lessons learnt report. Please read the selected report thoroughly before completing this questionnaire. The questionnaire should take approximately 2 hours to complete. The questions which are labelled with an (*) are required fields.

Due to the variation in methodological approaches and lessons learnt reports, some questions might be more suited to one case study than others, and some questions may not apply to certain case studies. If a question does not apply to a case study, please explain why.

*Name:	Harri Williams
*Organisation:	BRGM
*Date:	10.08.2021
*Case study evaluating *(please highlight)*:	Molasse Basin

Structural Framework

Do you agree with the following statements? :

5. * *In this case study, the structural framework has been successful in making the geology of the area more understandable.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

The structural framework is based from existing geological knowledge of the area therefore a good understanding of the areas geology is required before commencing. The structural framework simplifies and gives a contextual understanding of the complex fault network in the area.

6. * *In this case study, the structural framework has been successful in providing a coherent geological context for subsurface applications.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

The structural framework identifies large scale fault systems and demonstrates their relationship to the geological units in Bavaria. These fault systems make up an important compartmentation of prospective reservoirs, potentially highlighting areas of potential subsurface development.

7. *In this case study, the structural framework can aid in identifying and/or resolving subsurface management issues? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

The identification of fault systems will benefit the development of subsurface storage. Further work is required regarding this particular aspect.

* In this case study, what issues/barriers do you identify in applying the structural framework methodology? e.g large scale, large amounts of geological data, time consuming etc…

* Please explain your answer in a few sentences.

The Structural Framework is reliant on the utilization of present geological data and research. Areas clustered with large amounts of geological data are usually areas of past/ongoing subsurface significance e.g hydrocarbon prospectively, geothermal potential. Other areas which have not been so heavily researched such as the shallower parts of the Molasse Basin, have little geological data available.

Due to the complexities associated with the topic, in this case study the author determines that the SF has to be implemented by an expert team of geoscientists. It therefore might be difficult for stakeholders to use and interpret the system.

20. *In this case study, have you identified any fundamental issues / show stoppers / limitations regarding the application of the structural framework?*

* Please explain your answer in a few sentences.

In order to optimize subsurface planning, geological data for areas which have not necessarily been heavily researched in the past will be scarce. The SF will therefore potentially enhance our understanding in areas where there is already large amounts of geological data as these areas will have a more comprehensive geological picture.

The SF will however identify areas which are in need of further geological research.

21. *Do you have any further recommendations / suggestions which would benefit the application of the Structural Framework in this case study?*

Please explain the reason for your answer in a few sentences.

Geomanifestations

Do you agree with the following statements :

22. * *In this case study, geomanifestations have been successful as specific expressions that identify ongoing or past geological processes:*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> *** Please explain the reason for your choice in a few sentences.
>
> In Bavaria linear arrays of CO_2 rich springs have been identified in the very north-east of Bavaria. Dry maars and scoria cones characterisd by perculiar groundwater types and seismic events have also been identified.
>
> In the Molasse Basin there was a lack of geomanifistations or a lack of data to determine geomanifestations. No significant findings were therefore determined.

23. * *In this case study, geomanifestations have been successful in improving/completing the geological understanding:*

☐ Strongly disagree | ☒ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> The report fails to signify the significance of the geomanifiestations discovered such as CO2 rich springs and peculiar groundwater types in Bavaria. Therefore it is difficult to asses whether the geological understanding of the area has been improved through the use of Geomanifestations.

24. **In this case study, was the incorporation of Geomanifestations successful in helping identifying specific/potential management issues in the subsurface? E.g*

direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).

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* Please explain your answer in a few sentences.

The report does not identify any potential subsurface management issues.

The peculiar groundwater types could show areas of potential contamination.

The lessons learnt report does not go into sufficient detail identifying these parameters.

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25. ** In this case study, what are the issues/barriers concerning the application of Geomanifestations? e.g large scale, large amounts of geological data, time consuming etc…*

<div style="border:1px solid black; padding:10px;">

* Please explain your answer in a few sentences.

The main issue concerning the application of geomanifestations in this case study is the availability of data. The Molasse basin has very little data concerning geomanifestations and therefore the methodology could not be effectively applied.

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26. ** In this case study, have you identified any fundamental issues / show stoppers / limitations regarding the application of the Geomanifestations?*

*Please explain your answer in a few sentences.

Again, the availability of data as discussed above was one show stopper which ensured that the methodology had to be applied to a different area (Bavaria).

27. *Do you have any further recommendations / suggestions which would benefit the application of the Geomanifestations in this case study?*

Please explain the reason for your answer in a few sentences.

Structural Framework and Geomanifestations integration

Do you agree with the following statements :

28. * *The structural framework model annotated with geomanifestations enhances our understanding of the subsurface*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

With this case study, the methodology works well in Bavaria as bedrock is exposed or buried only by a thin layer of overburden. For instance, the recently evidenced maar close to the Bavarian-Czech border helped to focus the trend of one of the most important, but rarely observable structural features, the Tachov Fault Zone.

However, due to the thick overburden in the Molasse Basin, except for one, no surface or near surface geomanifestation can be related to the structural framework at depth.

29. * *The Structural Framework benefits from the incorporation of Geomanifestations into the model*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

Please give additional information if necessary.

Geomanifestations helped determine the trend of a rarely observable geological features in the area, the Tachov Fault Zone.

30. * *The Geomanifestations benefit from the context of the Structural Framework*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

Please give additional information if necessary.

When combing the SF and the GeoM in Bavaria, it is evident that the CO2 springs (GeoM) occur along fault zones in the SF. The inclusing of both sets of data gives much needed context.

31. *What barriers prevent both methodologies working (efficiently) together?*

* Please explain your answer in a few sentences.

All tectonic features of the Molasse Basin are buried under a thick succession of younger unreformed sediments meaning they cannot be detected and traced from surface exploration. Geomanifestations can therefore not be inferred to be related to the structural framework.

32. *Overall, has the methodology been applied successfully within the selected area, fulfilling the aims it set out to achieve? Please give a rating out of 10 and offer a brief explication in the box below.*

'The prime aim of GeoConnect³d is the conversion of geological data into subsurface information and critical parameters that can be used for various geo-applications, decision-making and subsurface spatial planning.'

☐	☐	☐	☐	☐	☒	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9	10

*Please explain the reason for your answer in a few sentences.

The structural framework is a good tool in order to visualise and simplify complex geological formations in the subsurface. It is also a good tool in order to identify large scale geological trends such as faulting.

The inclusion of geomanifestations is very dependent on data available, often residing in a clustering effect of geological data in areas of past research. Care must therefore be taken when trying to interprets patterns occurring within geomanifestations, as these patterns might only be a result of data availability.

When integrating the SF and GeoM within this case study, large amounts of sedimentary overburden has been shown to blur the availability of GeoM. Care must again be taken while inferring patterns between the SF and GeoM as patterns might again be due to availability of data.

The complexities associated with the production and interpretation of the methodology is highlighted by the author as a significant barrier to the utilisation of the methodology by industry stakeholders.

Other Questions

33. *Does the methodology offer additional benefits which were previously unaccounted for?*

Answer :

34. *Has the methodology opened up new opportunities for further development, exploration or valorisation?*

Answer :

WP5 - T5.3 Learning from the case studies

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Due to the variation in methodological approaches and lessons learnt reports, some questions might be more suited to one case study than others, and some questions may not apply to certain case studies. If a question does not apply to a case study, please explain why.

*Name:	Ales Havlin / Vit Hladik
*Organisation:	Czech geological survey
*Date:	15/09/2021
*Case study evaluating *(please highlight)*:	Roer-to-Rhine | Pannonian Basin | Ireland | Molasse Basin

Structural Framework

Do you agree with the following statements? :

8. * *In this case study, the structural framework has been successful in making the geology of the area more understandable.*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

> The study clearly and comprehensibly summarises and describes the geology of the area of interest, which is greatly assisted by the structural framework. The contribution of the framework to easier understanding of geology of the area is clearly shown.

9. * *In this case study, the structural framework has been successful in providing a coherent geological context for subsurface applications.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

The structural framework is a useful complement to overall geological information. At the scale at which the study was undertaken, we consider the structural framework to be beneficial, especially in the context of geothermal energy (with fault inventory as the main information source).

10. *In this case study, the structural framework can aid in identifying and/or resolving subsurface management issues? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

Thanks to the structural framework, the study contains signal information on some issues such as possible conflicts of interest. The use of information from the structural framework indicates areas where more detailed research and studies can be required. For detailed subsurface mgmt. issues, a more detailed scale of the framework would be needed.

11. * In this case study, what issues/barriers do you identify in applying the structural framework methodology? e.g large scale, large amounts of geological data, time consuming etc…

* Please explain your answer in a few sentences.

When working on relatively large areas, such as in the present study, one can always expect problems with consistency in the quality of input data, which entails time-consuming processing (especially if harmonization of input data, studies and information from various authors is to be performed).

35. * *In this case study, have you identified any fundamental issues / show stoppers / limitations regarding the application of the structural framework?*

> * Please explain your answer in a few sentences.
>
> The main limitation is probably the 2D (map) character of the framework. For its practical utilisation, e.g. for the subsurface management purposes, a 3D view (model) is needed in most cases. Another issue is the scale needed for efficient use in solving subsurface mgmt. issues (see above).

36. *Do you have any further recommendations / suggestions which would benefit the application of the Structural Framework in this case study?*

> Please explain the reason for your answer in a few sentences.
>
> No.

Geomanifestations

Do you agree with the following statements:

37. * *In this case study, geomanifestations have been successful as specific expressions that identify ongoing or past geological processes:*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> The study identified only very few geomanifestations in the Molasse Basin, which is partly surprising. If confirmed, this would signal that the concept of geomanifestations is unsuitable for geological areas of this type. On the other hand, there are good examples of geomanifestations provided for NE Bavaria, including the description of their relationships to geological processes.

38. * *In this case study, geomanifestations have been successful in improving/completing the geological understanding:*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> The study rather tried to interpret geomanifestations on the basis of existing geological knowledge. There are, however, a few examples mentioned when geomanifestations can help in improving the geological understanding.

39. *In this case study, was the incorporation of Geomanifestations successful in helping identifying specific/potential management issues in the subsurface? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

* Please explain your answer in a few sentences.

Yes, especially faults were identified as useful type of information for specific subsurface mgmt. issues (especially geothermal energy and energy storage). The description is, however, rather general.

40. * In this case study, what are the issues/barriers concerning the application of Geomanifestations? e.g large scale, large amounts of geological data, time consuming etc…*

* Please explain your answer in a few sentences.

The main barrier was the identified lack of geomanifestations in the Molasse Basin area.

41. * In this case study, have you identified any fundamental issues / show stoppers regarding the application of the Geomanifestations?*

*Please explain your answer in a few sentences.

The author identified a fundamental issue in domains where the bedrock is buried under thick strata of overburden, as the superposition of undeformed rocks blurs or obliterates the geomanifestations of the deep-seated structural framework, and we share this concern.

42. *Do you have any further recommendations / suggestions which would benefit the application of the Geomanifestations in this case study?*

No.

Structural Framework and Geomanifestations integration

Do you agree with the following statements?

43. * *The structural framework model annotated with geomanifestations enhances our understanding of the subsurface*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

Every relevant piece of information increases our understanding of the underground environment. The study, however, rather gives the impression that current knowledge and understanding of the subsurface was used to apply the structural framework and interpret geomanifestations.

44. *The Structural Framework benefits from the incorporation of Geomanifestations into the model*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

The study provides some indications of this but without sufficient level of detail.

45. *The Geomanifestations benefit from the context of the Structural Framework*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

The study provides some indications of this but without sufficient level of detail.

46. *What barriers prevent both methodologies working (efficiently) together?*

* Please explain your answer in a few sentences.

According to the study, the combination of these methodologies seems to work well only for specific types of geological settings, and is probably less suitable for others – see point 17.

Another issue is apparently the level of detail used for the structural framework that should correspond to the nature of geomanifestations, so that they can be linked to features shown in the framework.

47. *Overall, has the methodology been applied successfully within the selected area, fulfilling the aims it set out to achieve? Please give a rating out of 10 and offer a brief explication in the box below.*

'The prime aim of GeoConnect³d is the conversion of geological data into subsurface information and critical parameters that can be used for various geo-applications, decision-making and subsurface spatial planning.'

☐	☐	☐	☐	☐	☒	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9	10

The study demonstrates the possibility to use existing subsurface data from earlier national and international projects for application of the methodology developed by the project, on a case study with a partly transboundary scope. It identifies conflicting requirements of some data and model users.

The study gives examples of geomanifestations in NE-Bavaria but hardly any in the Molasse Basin. Possible use of a combination of structural framework with geomanifestations for subsurface mgmt. and planning is indicated but not discussed in detail.

We agree with the author that combining the Structural Framework and Geomanifestations can be a powerful tool for revision and evidencing the conceptual geological framework and the tectonic history of the area. This apparently works specifically well in areas where crystalline bedrock is exposed or covered by a thin overburden only. However, the methodology seems to be struggling in domains where the bedrock is buried under thick strata of overburden.The study successfully tested applicability of methods and approaches developed in WP3 and WP4 on a pilot study, even though the Bavaria case study cannot be considered "smaller-scale", and obviously required a lot of effort. The issues related to implementation of the structural framework and geomanifestations have mostly been successfully solved.

With respect to the objective of proposing improved methods for decision making for subsurface planning and management, in our opinion the study was only half-way successful because the methodology has proved useful only for part of the studied area. Moreover the Bundesland-scale structural framework is apparently too coarse for possible local subsurface planning applications.

Other Questions

48. *Does the methodology offer additional benefits which were previously unaccounted for?*

Answer :

Not identified.

49. *Has the methodology opened up new opportunities for further development, exploration or valorisation?*

Answer :

Yes, we consider this methodology suitable for further development and optimization for different areas of interest.

WP5 - T5.3 Learning from the case studies

Important information

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Due to the variation in methodological approaches and lessons learnt reports, some questions might be more suited to one case study than others, and some questions may not apply to certain case studies. If a question does not apply to a case study, please explain why.

*Name:	Tanja Petrović Pantić
*Organisation:	Geological survey of Serbia
*Date:	09.09.2021.
*Case study evaluating *(please highlight)*:	Roer-to-Rhine | Pannonian Basin | Ireland | **Molasse Basin**

Structural Framework

Do you agree with the following statements? :

12. * *In this case study, the structural framework has been successful in making the geology of the area more understandable.*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

> ** Please explain the reason for your choice in a few sentences.*
>
> A detailed display of the faults network and tectonic features gives better understanding of a geology in the area.

13. * *In this case study, the structural framework has been successful in providing a coherent geological context for subsurface applications.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

Based on the numerous subsurface data for deeper geological zones in Molasse basin and detailed geological investigations (geological map) in NE-Bavaria, Structural Framework provides a pretty clear geological context for subsurface applications.

14. *In this case study, the structural framework can aid in identifying and/or resolving subsurface management issues? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

* Please explain the reason for your choice in a few sentences.

In Bavaria, the use of subsurface is strongly defined by law. However, the Structural Framework can significantly facilitate planning and management of subsurface, considering that the decisions on the subsurface application are made by experts of the competent authorities.

15. * *In this case study, what issues/barriers do you identify in applying the structural framework methodology? e.g large scale, large amounts of geological data, time consuming etc…*

* Please explain your answer in a few sentences.

Covered tectonic features and scarce of data of shallow parts of Molasse Basin presented a barrier for application of this methodology.

50. * *In this case study, have you identified any fundamental issues / show stoppers / limitations regarding the application of the structural framework?*

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* Please explain your answer in a few sentences.

No

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51. *Do you have any further recommendations / suggestions which would benefit the application of the Structural Framework in this case study?*

Please explain the reason for your answer in a few sentences.

Geomanifestations

Do you agree with the following statements :

52. * *In this case study, geomanifestations have been successful as specific expressions that identify ongoing or past geological processes:*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

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* Please explain the reason for your choice in a few sentences.

In the case of Molasse Basin, geomanifestations are the result of geological processes (glacial and inter-/post-glacial processes). Also, in this case, geomanifestations are related to the faults.

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53. * *In this case study, geomanifestations have been successful in improving/completing the geological understanding:*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

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* Please explain the reason for your choice in a few sentences.

In the case of Bavaria, geomanifestations improving the geological understanding, these are a reflecton on past or ongoing geological process. In the other case of Molasse Basin, there is not enough evidence from geomanifestations.

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54. *In this case study, was the incorporation of Geomanifestations successful in helping identifying specific/potential management issues in the subsurface? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

* Please explain your answer in a few sentences.

Incorporation of geomanifestations definitively can help to identify potential issues in the subsurface. There is a doubt if underground energy storage and geothermal energy can induce or trigger seismicity, which should be taken into account.

55. * In this case study, what are the issues/barriers concerning the application of Geomanifestations? e.g large scale, large amounts of geological data, time consuming etc…*

* Please explain your answer in a few sentences.

Lack of geomanifestations in Mollase basin, did not give opportunitiy to apply this methodology.

56. * In this case study, have you identified any fundamental issues / show stoppers regarding the application of the Geomanifestations?*

*Please explain your answer in a few sentences.

If we think about geomanifestations as one of the methodologies in this study, it is obvious that more data are necessary to apply methodology (case of Molasse basin). But if we think on geomanifestation application in reality, there is a doubt that some geomanifestations as underground energy storage and geothermal energy can induce or trigger seismicity, which should be taken into account.

57. *Do you have any further recommendations / suggestions which would benefit the application of the Geomanifestations in this case study?*

Please explain the reason for your answer in a few sentences.

Structural Framework and Geomanifestations integration

Do you agree with the following statements :

58. * *The structural framework model annotated with geomanifestations enhances our understanding of the subsurface*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

* Please explain the reason for your choice in a few sentences.

In the case of Molasse basin, a scarce of geomanifestations does not show intense relationship with structural framework.

In Bavaria, it emphasizes intense relationship between geomanifestations and structural framework. In that case I can strongly agree with statement above.

In any case, combining both methodologies can be a very helpful for providing the conceptual framework, the tectonic history and processes.

59. * *The Structural Framework benefits from the incorporation of Geomanifestations into the model*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

Please give additional information if necessary.

In the Molasse Basin, geomanifestations (elaveted temperature of groundwater) didn't gave reliable information about the faults.

In NE Bavaria, geomanifestations didn't gave benefit to structural framework, due to complexity of tectonic boundary. In other hand, it is noticed importance of some geomanifestations in understanding of some structural characteristic (in a larger scale).

60. * *The Geomanifestations benefit from the context of the Structural Framework*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

Please give additional information if necessary.

Relationship between geomanifestations and structural framework can help us to estimate reserves of geomanifestations, forecast new appearances of geomanifestations and new investigations (e.g. new drilling of geothermal wells).

61. *What barriers prevent both methodologies working (efficiently) together?*

* Please explain your answer in a few sentences.

In the area where the bedrock is covered with thick layers, both methodologies are not applicable.

62. *Overall, has the methodology been applied successfully within the selected area, fulfilling the aims it set out to achieve? Please give a rating out of 10 and offer a brief explication in the box below.*

'The prime aim of GeoConnect³d is the conversion of geological data into subsurface information and critical parameters that can be used for various geo-applications, decision-making and subsurface spatial planning.'

☐	☐	☐	☐	☐	☐	☐	☒	☐	☐
1	2	3	4	5	6	7	8	9	10

*Please explain the reason for your answer in a few sentence

Methodology gives great results when geomanifestations are visible and it is clear connection with structural framework, but in the case when there is not enough evidence of geomanifestation or in area where tectonic features are not easily visible on surface, this method does not give sufficient results.

Other Questions

63. *Does the methodology offer additional benefits which were previously unaccounted for?*

Answer :

Yes. This methodology gives better view and knowledge of geological history, tectonic features and better geological understanding. Also it is helpful for decision-makers and better subsurface management.

64. *Has the methodology opened up new opportunities for further development, exploration or valorisation?*

Answer :

Absolutely. Good knowledge of geological features, history, geomanifestations gives us opportunity to better manage resources (e.g. geothermal, gas seeps, same ore), exploit them and preserve them.

WP5 - T5.3 Learning from the case studies

Important information

The questionnaire will be based from each case study's lessons learnt report. Please read the selected report thoroughly before completing this questionnaire. The questionnaire should take approximately 2 hours to complete. The questions which are labelled with an (*) are required fields.

Due to the variation in methodological approaches and lessons learnt reports, some questions might be more suited to one case study than others, and some questions may not apply to certain case studies. If a question does not apply to a case study, please explain why.

*Name:	**Miloš Markič**
*Organisation:	**Geological Survey of Slovenia**
*Date:	**10. 9. 2021**
*Case study evaluating *(please highlight)*:	Roer-to-Rhine | Pannonian Basin | Ireland | **Molasse Basin**

Structural Framework

Do you agree with the following statements? :

16. * *In this case study, the structural framework has been successful in making the geology of the area more understandable.*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> Geology, tectonic development, and present structural framework (SF) are clearly presented for the studied area as expected within the aims of the GeoConnect3d project.

17. * *In this case study, the structural framework has been successful in providing a coherent geological context for subsurface applications.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> SF has been successfully used in providing information on subsurface applications on basis of published and accessible data as available to the author. However, a kingdom of crucial data is most probably still under the "ownership" of oil and gas, and geothermal etc. companies.

18. *In this case study, the structural framework can aid in identifying and/or resolving subsurface management issues? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

SF as presented in the study based on published data is in general very well presented. But detailed data, most probably confidential, are in specific projects and data bases of companies. And all possibilities of underground usage in Germany have not been explored and/or are banned at least to some degree (e.g. CO_2 storage, unconventional high volume hydrofracturing). -

19. * In this case study, what issues/barriers do you identify in applying the structural framework methodology? e.g large scale, large amounts of geological data, time consuming etc…

* Please explain your answer in a few sentences.

Large scale SF data and compilations are welcome, however details for real decisions how to manage, use and care for subsurface applications are still missing (over the role of the GeoConnect3d project and the author).

65. * In this case study, have you identified any fundamental issues / show stoppers / limitations regarding the application of the structural framework?

* Please explain your answer in a few sentences.

I did not identify fundamental issues concerning available data and "published" knowledge.

66. Do you have any further recommendations / suggestions which would benefit the application of the Structural Framework in this case study?

Please explain the reason for your answer in a few sentences.

SF for the Molasse Basin and NE Bavaria is in general well explained both scientifically and practically. However, more detailed structural frameworks (SFs) for particularly interesting areas and sites would be highly appreciated in the future.

Geomanifestations

Do you agree with the following statements :

67. * *In this case study, geomanifestations have been successful as specific expressions that identify ongoing or past geological processes:*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

> *** Please explain the reason for your choice in a few sentences.
>
> Yes, presentation and explanation of geomanifestations (GMs) are well presented in the study. It is clearly understandable that they almost not occur within the Molasse basin but they occur in connection with SF in the NE Bavaria structural units.

68. * *In this case study, geomanifestations have been successful in improving/completing the geological understanding:*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> *** Please explain the reason for your choice in a few sentences.
>
> Yes, GMs, especially dense in the territory of NE Bavaria – Saxothuringian Zone, contributed to geological understanding. Studying GMs in connection with SF will always be interesting and usable from scientific and practical reasons.

69. *In this case study, was the incorporation of Geomanifestations successful in helping identifying specific/potential management issues in the subsurface? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

* Please explain your answer in a few sentences.

GMs can help in subsurface management and can represent a good information, even a guide in identifying subsurface circumstances including evaluation of geopotentials. GMs are often a consequence of different extreme geological conditions, e.g., elevated temperatures, hydrothermal flows, faults, geochemical anomalies, volcanic activities etc. In Bavaria underground mines do not operate anymore with one exception, a graphite mine, in the south of Bohemia. To prevent eventual hazards a strict Mining law regulates licences in a way that only one subsurface utilization is allowed for one licence area. An exception is that geothermal energy from >2 km depth can be utilized beneath groundwater abstraction if separated by a thick barrier horizon.

70. * In this case study, what are the issues/barriers concerning the application of Geomanifestations? e.g large scale, large amounts of geological data, time consuming etc…

* Please explain your answer in a few sentences.

GMs are well documented on the surface. In many cases they have an explanation in the deep underground, known e.g from exploration for oil and gas, geothermal, mineral waters, ore, and coal mining etc. But concerning SF its tectonic elements are often subcropping, therefore a direct observation of relationship between GMs and e.g. faults is frequently not possible. Data of high value exist particularly for "deep geology" sourcing from hydrocarbons and deep geothermal explorations. For "shallow geology" information is more scarce.

71. * In this case study, have you identified any fundamental issues / show stoppers regarding the application of the Geomanifestations?

*Please explain your answer in a few sentences.

Interpretation of GMs and "deep geology" including its SF is still questionable in considerable geological realms of Bavaria. GMs are good understood in areas of existing or past geological exploration sites and areas of mineral and energy exploitation.

72. *Do you have any further recommendations / suggestions which would benefit the application of the Geomanifestations in this case study?*

Please explain the reason for your answer in a few sentences.

I recommend just to continue with detecting, studying documenting and public dissemination of GMs. Geomanifestations can in many cases lead to n better understanding of geological phenomena and processes going on in the close, medium and deep geological realms.

Structural Framework and Geomanifestations integration

Do you agree with the following statements :

73. * *The structural framework model annotated with geomanifestations enhances our understanding of the subsurface*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

Understanding the subsurface needs much more than to know only SF and GMs. But in the frame of available data and "published Knowledge the study fulfilled its targets and aims.

74. * *The Structural Framework benefits from the incorporation of Geomanifestations into the model*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

Please give additional information if necessary.

Yes for NE Bavaria SF and GMs relations were clearly identified.

75. * *The Geomanifestations benefit from the context of the Structural Framework*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

Please give additional information if necessary.

Yes, it is clearly concluded in the study that in NE Bavaria, where pre-Tertiary basement is outcropping with visible tectonic structures GMs are clearly connected with SF. So, GMs benefit from SF.

76. *What barriers prevent both methodologies working (efficiently) together?*

* Please explain your answer in a few sentences.

The concept of GMs and especially expression "Geomanifestations" is a new one, unless known substantially for a long time as e.g**., "**geological phenomena" on the surface. How to work efficiently both methodologies together is a question of our will, scientific and practical interests, money/data to combine both domains more tightly.

77. *Overall, has the methodology been applied successfully within the selected area, fulfilling the aims it set out to achieve? Please give a rating out of 10 and offer a brief explication in the box below.*

'The prime aim of GeoConnect³d is the conversion of geological data into subsurface information and critical parameters that can be used for various geo-applications, decision-making and subsurface spatial planning.'

☐	☐	☐	☐	☐	☐	☐	☒	☐	☐
1	2	3	4	5	6	7	8	9	10

*Please explain the reason for your answer in a few sentences.

The whole GeoConnect3d project was very welcome. As for many EU projects its benefit was in joining/meeting geologists from the EU geological surveys getting acquainted with geology of different geological realms. Project was very well organised and guided. Critical evaluation of the works done for the chosen areas (Roer-to-Rhine, Pannonian Basin, Ireland, and Molasse Basin and NE Bavaria) increased the value of the project. However still considerable number of questions remained open and call for further studies (the reason for my rating 8).

Other Questions

78. *Does the methodology offer additional benefits which were previously unaccounted for?*

Answer :

More contacts with industry and direct subsurface managing companies/firms to get primary data of high value would be recommended in the future.

79. *Has the methodology opened up new opportunities for further development, exploration or valorisation?*

Answer :

Yes, it did. But always crucial will be the possibility to get access to real data, and acquisition of new data.

WP5 - T5.3 Learning from the case studies

Important information

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Due to the variation in methodological approaches and lessons learnt reports, some questions might be more suited to one case study than others, and some questions may not apply to certain case studies. If a question does not apply to a case study, please explain why.

*Name:	Russell Rogers
*Organisation:	GSI
*Date:	20/08/2021
*Case study evaluating *(please highlight)*:	Roer-to-Rhine | Pannonian Basin | Ireland | <mark>Molasse Basin</mark>

Structural Framework

Do you agree with the following statements? :

20. * *In this case study, the structural framework has been successful in making the geology of the area more understandable.*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

---

* Please explain the reason for your choice in a few sentences.

The structural framework in this area streamlines the geology, synthesizing many years of interpretation into a high level overview of the geological domains.

---

21. * *In this case study, the structural framework has been successful in providing a coherent geological context for subsurface applications.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☒ Strongly agree

* Please explain the reason for your choice in a few sentences.

The structural framework is effective in breaking down geology into understandable units on a regional scale, which will provide context for data examined on a local or project scale.

22. *In this case study, the structural framework can aid in identifying and/or resolving subsurface management issues? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

The structural will aid in identifying conflicts of use, zones of influence etc on a very broad scale. Decision makers will know immediately that projects are or are not within the same lithotectonic unit, but spatial variations within a lithotectonic unit will not be apparent and will require further data.

23. * In this case study, what issues/barriers do you identify in applying the structural framework methodology? e.g large scale, large amounts of geological data, time consuming etc…

* Please explain your answer in a few sentences.

A wide variety of data sources collected using different methods, and different techniques within a method, present a very complicated decision tree for producing a single interpreted product.

80. * *In this case study, have you identified any fundamental issues / show stoppers / limitations regarding the application of the structural framework?*

* Please explain your answer in a few sentences.

No, the structural framework seems well applied and a useful tool.

81. *Do you have any further recommendations / suggestions which would benefit the application of the Structural Framework in this case study?*

Please explain the reason for your answer in a few sentences.

I think the structural framework units could be further refined, the Central Foreland Molasse Basin, for example, is presented here as a very large homogenous unit.

Geomanifestations

Do you agree with the following statements :

82. * *In this case study, geomanifestations have been successful as specific expressions that identify ongoing or past geological processes:*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> Yes, the text points out that some of the geomanifestations confirm or refine features of the structural framework.

83. * *In this case study, geomanifestations have been successful in improving/completing the geological understanding:*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> I think the geomanifestations as explained in the text further characterise the features that they are related to.

84. *In this case study, was the incorporation of Geomanifestations successful in helping identifying specific/potential management issues in the subsurface? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

* Please explain your answer in a few sentences.

No. I believe the authors used the geomanifestations to confirm and refine the structural framework, but the geomanifestations in isolation do not add any information that is not available in the structural framework

85. * In this case study, what are the issues/barriers concerning the application of Geomanifestations? e.g large scale, large amounts of geological data, time consuming etc…

* Please explain your answer in a few sentences.

As explained in the text, the nature of the geology of the region makes geomanifestations difficult to implement, e.g. everything being buried very deeply in the Molasse Basin

86. * In this case study, have you identified any fundamental issues / show stoppers regarding the application of the Geomanifestations?

*Please explain your answer in a few sentences.

I think that the over-arching definition of a GeoManifestation could be refined to allow their applications. The author emphasizes their application of the definition of GeoManifestation and a relaxing of this definition may enable other features to be used.

87. *Do you have any further recommendations / suggestions which would benefit the application of the Geomanifestations in this case study?*

Please explain the reason for your answer in a few sentences.

Structural Framework and Geomanifestations integration

Do you agree with the following statements :

88. * *The structural framework model annotated with geomanifestations enhances our understanding of the subsurface*

☒ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

The information provided by both geomanifestations and the structural framework improve the *ability to communicate* the current understanding of the subsurface, rather than improving the understanding itself

89. * *The Structural Framework benefits from the incorporation of Geomanifestations into the model*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

Please give additional information if necessary.

Clearly the author has identified uses for the geomanifestations to refine or confirm features of the structural framework.

90. * *The Geomanifestations benefit from the context of the Structural Framework*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

Please give additional information if necessary.

It would be impossible to make any use of the geomanifestations without the geological understanding conveyed by the SF

91. *What barriers prevent both methodologies working (efficiently) together?*

* Please explain your answer in a few sentences.

I believe GeoManifestations could be redefined to provide an effective application in this case area

92. *Overall, has the methodology been applied successfully within the selected area, fulfilling the aims it set out to achieve? Please give a rating out of 10 and offer a brief explication in the box below.*

'The prime aim of GeoConnect³d is the conversion of geological data into subsurface information and critical parameters that can be used for various geo-applications, decision-making and subsurface spatial planning.'

☐	☐	☐	☐	☐	☐	☐	☐	☒	☐
1	2	3	4	5	6	7	8	9	10

*Please explain the reason for your answer in a few sentences.

 I would like to see more detail of the larger units in the SF, BUT I am aware of the time limits and the difficulty of the task

Other Questions

93. *Does the methodology offer additional benefits which were previously unaccounted for?*

Answer :

No

94. *Has the methodology opened up new opportunities for further development, exploration or valorisation?*

Answer :

The refinement of features of the SF using the GeoManifestations will have impacts on other geological products e.g. Maps for expert stakeholders.

WP5 - T5.3 Learning from the case studies

Important information

The questionnaire will be based from each case study's lessons learnt report. Please read the selected report thoroughly before completing this questionnaire. The questionnaire should take approximately 2 hours to complete. The questions which are labelled with an (*) are required fields.

Due to the variation in methodological approaches and lessons learnt reports, some questions might be more suited to one case study than others, and some questions may not apply to certain case studies. If a question does not apply to a case study, please explain why.

*****Name:**	**Monika Konieczyńska, Joanna Fajfer**
*****Organisation:**	**PIG-PIB**
*****Date:**	**15.09.2021**
*****Case study evaluating** *(please highlight)*:	Roer-to-Rhine | Pannonian Basin | Ireland | **Molasse Basin**

Structural Framework

Do you agree with the following statements? :

24. * *In this case study, the structural framework has been successful in making the geology of the area more understandable.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> This report presents a decent traditional description of the geology of the studied region but there is no actual visualization of structural framework itself, neither for Molasse Basin, nor for northern Bavaria (which is added, because according to the author - geomanifestations can be found there). As author stresses - the presented SFcompilation does not strive for giving a full inventory of tectonic features but aims at stressing the contextual relationship of the fault network and its relation to the geological units. So there is a problem to assess: "more" compared to what?

25. * *In this case study, the structural framework has been successful in providing a coherent geological context for subsurface applications.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

Yes. It gives a coherent context for relation between faults and geological units, but still it has the same shortages to be used for subsurface applications management as SF in general has at this stage - mainly lack of 3D context.

26. *In this case study, the structural framework can aid in identifying and/or resolving subsurface management issues? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

* Please explain the reason for your choice in a few sentences.

Yes, according to the author, the SF presented in the case study may be helpful in identifying problems related to the use of underground space. The most important information for the development of underground space is the knowledge on the location of the fault network in each region. Unfortunately, due to the complexity of the subject, GC3d SF is only the first step in the right direction and needs to be operated by geoscientists as even experienced laypersons have not the capability to interpret basic geoscience data or interpretations.

27. * In this case study, what issues/barriers do you identify in applying the structural framework methodology? e.g large scale, large amounts of geological data, time consuming etc…

* Please explain your answer in a few sentences.

Scattered data on detailed recognition focusing on hydrocarbons prospection and geothermal projects areas. Cross border area only possible to be presented with use of geological information from abroad.

95. * In this case study, have you identified any fundamental issues / show stoppers / limitations regarding the application of the structural framework?

* Please explain your answer in a few sentences.

All possible SF features – lines are hidden under the thick overburden and must have been interpreted only from geophysical records. No surface geomanifestations to be connected to limits and units of Molasse Basin.

96. Do you have any further recommendations / suggestions which would benefit the application of the Structural Framework in this case study?

Please explain the reason for your answer in a few sentences.

Molasse Basin can be regarded as similar case as lowlands of central and eastern Europe, only in smaller scale. It shows all the problems with hidden structures to be recognized, aggregated where needed and presented in a comprehensive way. Also the need to use cross border and other country data as well as industry derived data applies to e.g. Mesozoic basins further NE from Bavaria. In our opinion this aspects of SF implementation could have been more discussed and some views on overcoming problems might have been presented.

We agree that SF concept needs to be further refining and has a potential to become a powerful tool in subsurface use management. No directions of the further development have been shown unfortunately.

Geomanifestations

Do you agree with the following statements :

97. * *In this case study, geomanifestations have been successful as specific expressions that identify ongoing or past geological processes:*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> The lack of GMs on the surface in the area of Molasse Basin was considered as a stopper for application of GMs concepts into SF. It is not clear why subsurface data, coming e.g. from boreholes logs, like temperature anomalies have not been incorporated - was it the lack of data or "author's understanding" of GM term?
>
> But even in N Bavaria, GMs do not really follow the fault pattern and only in some cases they were somewhat helpful in revising and evidencing the conceptual framework of the tectonic history and improve the understanding of the recent kinematic processes (e.g. volcanic mare near the Bavarian-Czech border helped to focus on the trend of one of the most important but rarely observable structural feature, the Tachov Fault Zone).

98. * *In this case study, geomanifestations have been successful in improving/completing the geological understanding:*

☒ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> In this case it seems that GMs incorporation into SF has not been worked over, most of the work was done based on existing maps and literature.

99. **In this case study, was the incorporation of Geomanifestations successful in helping identifying specific/potential management issues in the subsurface? E.g*

direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).

> * Please explain your answer in a few sentences.
>
> No, according to the author - the method is not applicable in domains where the bedrock is buried under thick strata of overburden, as the superposition of undeformed rocks blurs or obliterates the Geomanifestations (if there are any) of the deep-seated Structural Framework.

100.   ** In this case study, what are the issues/barriers concerning the application of Geomanifestations? e.g large scale, large amounts of geological data, time consuming etc…*

> * Please explain your answer in a few sentences.
>
> The main barrier is the lack of geomanifestations on the surface in the questioned area of Molasse basin.

101.   ** In this case study, have you identified any fundamental issues / show stoppers regarding the application of the Geomanifestations?*

> ***Please explain your answer in a few sentences.
>
> The only problem here is the lack of GMs reported by the author.

102.   *Do you have any further recommendations / suggestions which would benefit the application of the Geomanifestations in this case study?*

> Please explain the reason for your answer in a few sentences.
>
> We would recommend enlarging the list of GMs in Molasse Basin with data from hydrocarbons exploitation and geothermal applications, maybe some mass movements observations(?). Maybe this would add to the whole view?

Structural Framework and Geomanifestations integration

Do you agree with the following statements :

103.   ** The structural framework model annotated with geomanifestations enhances our understanding of the subsurface*

☒ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

> * Please explain the reason for your choice in a few sentences.
>
> There are no GMs integrated in the SF ArcGIS file.
>
> Based on the report text - there is very little discussed on this issue.

104. * *The Structural Framework benefits from the incorporation of Geomanifestations into the model*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

> Please give additional information if necessary.
>
> In this case, it is difficult to establish such a relationship. The only observed GM in Molasse Basin - elevated water temperature in shallow water wells cannot be related to particular feature of the SF. In the N Bavaria some benefits in case of volcanic fingerprints can be observed.

105. * *The Geomanifestations benefit from the context of the Structural Framework*

☐ Strongly disagree | ☒ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> Please give additional information if necessary.
>
> There are no geomanifestations integrated in the SF ArcGIS file and this is not presented in the report.

106. **What barriers prevent both methodologies working (efficiently) together?*

> * Please explain your answer in a few sentences.
>
> No GMs in the questioned region.

107. **Overall, has the methodology been applied successfully within the selected area, fulfilling the aims it set out to achieve? Please give a rating out of 10 and offer a brief explication in the box below.*

'The prime aim of GeoConnect³d is the conversion of geological data into subsurface information and critical parameters that can be used for various geo-applications, decision-making and subsurface spatial planning.'

☐	☐	☐	☒	☐	☐	☐	☐	☐	☐
1	2	3	4	5	6	7	8	9	10

The SF presented in the case study was prepared based on the existing maps, interpretations and harmonization already done in the past (at least it seems to be like this). No discussion on aggregation criteria is presented (but maybe not needed). Neither the way how to use it in planning and management procedures is suggested. The scope of GMs that had been identified in order to add something to Molasse basin geological knowledge in our opinion was too scarce, but maybe there is nothing else indeed (we have not got sufficient knowledge to judge).

Some difficulties in SF formulation in case of structures with no outcrops on the surface was presented and some future development directions was suggested.

Other Questions

108.   *Does the methodology offer additional benefits which were previously unaccounted for?*

Answer :

It does not seem to.

109.   *Has the methodology opened up new opportunities for further development, exploration or valorisation?*

Answer :

Accordin to the author : The multi-scale method for the Structural Framework is a very good approach to visualize the "hierarchy" of the tectonic units and their subdivision. However, to ensure comparability of the level in the hierarchy applied by different authors, it requires a review and re-mastering following common criteria.

    and :

Undoubtedly, the Structural Framework as conceptualized in GeoConnect3d is the first step into the right direction, setting up an expert tool for a first approach on optimising subsurface planning. With further refinement it might become a powerful tool for the prioritisation/optimisation of subsurface utilizations and the derivation of recommendations and solutions and information in understandable form that can be used and exploited by planner and decision makers.

Important information

The questionnaire will be based from each case study's lessons learnt report. Please read the selected report thoroughly before completing this questionnaire. The questionnaire should take approximately 2 hours to complete. The questions which are labelled with an (*) are required fields.

Due to the variation in methodological approaches and lessons learnt reports, some questions might be more suited to one case study than others, and some questions may not apply to certain case studies. If a question does not apply to a case study, please explain why.

*Name:	Johanna Van Daele
*Organisation:	VPO
*Date:	10-09-2021
*Case study evaluating *(please highlight)*:	Roer-to-Rhine | Pannonian Basin | Ireland | Molasse Basin

Structural Framework

Do you agree with the following statements? :

28. * *In this case study, the structural framework has been successful in making the geology of the area more understandable.*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

> The Structural Framework (SF) of the Molasse Basin certainly does bring the regional geology in a very understandable and accessible way. Based on the introduction given in the report, I have the impression that the geology of the study area was already very well-understood prior to the construction of the SF. But, as also mentioned in the report, the zoom scale system has great added value.

29. * *In this case study, the structural framework has been successful in providing a coherent geological context for subsurface applications.*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

The SF provides an excellent overview of the geotectonic structure of the Molasse Basin. More specifically, the compartimentalisation of reservoirs and seal integrity, the main conduits of fluid flow and potential structural traps, are important geological factors that need to be considered for almost all subsurface applications.

30. *In this case study, the structural framework can aid in identifying and/or resolving subsurface management issues? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

☐ Strongly disagree | ☒ Somewhat disagree | ☐ Somewhat agree | ☐ Strongly agree

It is not clear to me how the constructed SF can contribute to the above-mentioned, specific subsurface management issues, other than with a generally increased knowledge of the subsurface (as discussed in question 2).

31. * In this case study, what issues/barriers do you identify in applying the structural framework methodology? e.g large scale, large amounts of geological data, time consuming etc…*

Lot of information is available for the Molasse Basin, however, mostly clustered in areas of hydrocarbon prospectivity and high geothermal potential. Additionally, most faults and other features are covered by a thick overburden and hence don't appear at the surface.

Also, the Structural Framework is derived from a multitude of sources and indirect evidence, hence should not considered as a full inventory of tectonic features. This (inevitable) incompleteness possible can be a barrier in its application.

110.   *In this case study, have you identified any fundamental issues / show stoppers / limitations regarding the application of the structural framework?*

No, in my opinion, the SF really provides a solid, high-quality geological framework of the area. It highlights the contextual relationship of the fault network and its relation to the different geological units.

111.   *Do you have any further recommendations / suggestions which would benefit the application of the Structural Framework in this case study?*

Maybe it would be worthwhile to include the recent sedimentary cover in a bit more detail in the SF. If I remember correctly, that has been done for the Pannonian Basin.

Geomanifestations

Do you agree with the following statements :

112.   * *In this case study, geomanifestations have been successful as specific expressions that identify ongoing or past geological processes:*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

> Yes. The upwelling thermal water in the Molasse Basin (s.s.) evidences upwards fluid flow along the Landshut-Neuötting Step Fault. Similarly, the linear array of CO_2-springs, peculiar groundwater chemistry and seismic events in NE Bavaria indicate on-going geological processes in the deep subsurface, often related to the presence of deep-seated, permeable faults. The ore veins and linear array of dry maars and scoria cones are remnants of past fluid and volcanic activity in NE Bavaria.

113.   * *In this case study, geomanifestations have been successful in improving/completing the geological understanding:*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

> The aligned Geomanifestations (GM) offered support for mapping tectonic boundaries, i.e. to further refine the position of the important Tachov Fault Zone. Additionally, the Geomanifestations can help to revise and evidence the conceptual framework of the tectonic history and to improve the understanding of recent kinematic processes.

114. *In this case study, was the incorporation of Geomanifestations successful in helping identifying specific/potential management issues in the subsurface? E.g direct/indirect conflicts of use; zones of influence; areas of potential reuse and synergies; potential hazards etc… (please discuss multiple options if necessary).*

I don't see immediate implications of the inventoried Geomanifestations to help in specific subsurface management issues. They mainly increase the general geological understanding of the Molasse Basin, and hence play an indirect role in this.

115. * In this case study, what are the issues/barriers concerning the application of Geomanifestations? e.g large scale, large amounts of geological data, time consuming etc…*

The main challenge for identifying useful Geomanifestations in the Molasse Basin (s.s.) lies in the thick overburden cover, which prevents clear expressions and observations of Geomanifestations at the surface that relate to the Structural Framework. Most of the Geomanifestation in the Molasse Basin are the result of glacial and inter-/post-glacial processes sculpting the landscape in more recent times, and thus not applicable to the subsurface. The Geomanifestations in NE-Bavaria are readily applicable.

116. * In this case study, have you identified any fundamental issues / show stoppers regarding the application of the Geomanifestations?*

No, the inventoried Geomanifestations provide valuable information for the (undeep) Bavarian geology also without being tied to the SF.

117.   *Do you have any further recommendations / suggestions which would benefit the application of the Geomanifestations in this case study?*

It is mentioned that the GM should be considered as a back-testing rather than a way to gain new knowledge, but I think a more focused research on the Geomanifestations (e.g., C-isotopes of the CO_2-springs, paragenesis of the ore veins, …) could potentially increase the knowledge of the processes that play(ed) in the origin of these Geomanifestations, and hence shed more light on the fault network characteristics.

Structural Framework and Geomanifestations integration

Do you agree with the following statements :

118.   * *The structural framework model annotated with geomanifestations enhances our understanding of the subsurface*

☐ Strongly disagree | ☐ Somewhat disagree | ☐ Somewhat agree | ☒ Strongly agree

The combination of the SF and the Geomanifestations database certainly improves the understanding of the Bavarian subsurface, both in terms of the location of faults and their permeability.

119.   *The Structural Framework benefits from the incorporation of Geomanifestations into the model*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☒ Strongly agree

The Geomanifestations, though limited, can help to revise and evidence the conceptual tectonic framework, and improve the understanding of past or on-going kinematic processes (e.g., seismicity along the Tachov Fault Zone).

120.   *The Geomanifestations benefit from the context of the Structural Framework*

☐ Strongly disagree | ☐ Somewhat disagree | ☒ Somewhat agree | ☐ Strongly agree

No detailed information on the Geomanifestations is given, but it seems to me that the Geomanifestations were collected entirely independently of the SF and that no new entries were added after the construction of the SF or the SF-GM combination exercise. Nevertheless, the process behind the inventoried Geomanifestations often was clarified with aid of the SF.

121. *What barriers prevent both methodologies working (efficiently) together?

The main barrier is a geological one, i.e. the thick overburden in the Molasse Basin, which prevents the observation of relevant Geomanifestations that are related to the constructed SF of the deep subsurface.

122. *Overall, has the methodology been applied successfully within the selected area, fulfilling the aims it set out to achieve? Please give a rating out of 10 and offer a brief explication in the box below.

'The prime aim of GeoConnect³d is the conversion of geological data into subsurface information and critical parameters that can be used for various geo-applications, decision-making and subsurface spatial planning.'

☐	☐	☐	☐	☐	☐	☐	☒	☐	☐
1	2	3	4	5	6	7	8	9	10

The Structural Framework and Geomanifestations greatly contribute to summarizing and visualizing subsurface information of the state of Bavaria. The SF especially provides a powerful tool to explain the hierarchy of tectonic units to non-experts in an accessible way. The Geomanifestations give support in finetuning the SF and in some cases adding fault characteristics information.

The SF and GM surely provide content-wise help for subsurface management as well, given the increased knowledge and 3D information obtained from it. However, I cannot really assess the specific applicability to decision-making and subsurface planning cases, as this aspect is not elaborately discussed in the report and I am not very aware of the existing subsurface management issues in Bavaria.

Other Questions

123. *Does the methodology offer additional benefits which were previously unaccounted for?*

Answer : /

124. *Has the methodology opened up new opportunities for further development, exploration or valorisation?*

Answer : /