Earth Syst. Sci. Data Discuss.,
https://doi.org/10.5194/essd-2020-139-RC2, 2020

Open Access Earth System Science Data Discussions

Interactive comment on "Petrophysical and mechanical rock property database of the Los Humeros and Acoculco geothermal fields (Mexico)" *by* Leandra M. Weydt et al.

Léa Lévy (Referee)

lea.levy@geo.au.dk

Received and published: 16 August 2020

Pdf attached has better formatting.

1. General comments on the paper

The manuscript presents a unique, robust and extensive database of a large range of petrophysical, mineralogical and chemical properties of volcanic rocks from two geothermal fields in Mexico. The workflow and methods are well described. It also presents some limitations in relation to the use of data. The database is easily accessible from one unique excel file, which is (surprisingly!) only 1.7 Mo and can be

open without issues. Moreover, I find it easy to navigate and understand the database. Standard deviations of most measured parameters are clearly presented, which will be of great value for future users, especially for feeding geo-statistical analyses.

I consider this manuscript suitable for publication but I suggest a moderate revision in order to address two important changes in the paper, which are required in my opinion:

(i) More explanations about the lack of electrical measurements (50 samples versus 1000-1500 for all other properties) and the implications for statistical analyses and MT/TEM/DC surveys interpretations. MT and TEM are among the most common methods (if not the most) used in geothermal exploration, so this discussion is critical to justify the usefulness of your paper. The paper also should help the reader find ways to overcome this gap. Additionally, the use of ERT for inferring the resistivity of samples is not a state-of-the-art method and it is not clear how many of the 50 samples are inferred from ERT. Especially because 50 samples have a formation factor, which I guess you cannot obtain with only ERT measurements. More clarity is needed here.

(ii) Clearer aim and context. References and comparison to recent, similar and complementary studies are lacking. Especially to feed the discussion on how to overcome limitations of this specific database. I have suggested a few studies that I know of and consider complementary.

2. Specific comments related to the scientific content

I find the aim of this study somewhat unclear but I think it could be easily improved. In the abstract you only mention "overcome the gap of knowledge of the reservoir properties". It could be clearer, more specific and also presented with more perspective and context. This would make the paper and database immediately relevant for a large audience and allow exciting scientific discussion. It would show the usefulness of the database in a clearer manner.

To be more specific, my main question after reading the paper is: Is this database only

intended at interpreting geophysical datasets in the two corresponding areas in Mexico, for this corresponding deepEGS exploration project? Or do you see possibilities to use this database at other geothermal fields, for different geothermal exploration projects?

- If this is only for the present exploration project in Mexico, are you then suggesting that such extensive data collection be done for every geothermal system to be explored? It would be interesting to get an idea of how much resource it requires, compared to other exploration costs. Is it realistic? Are we going to need public funds for every new geothermal exploration project? Or is there a point where we will have hopefully collected enough petrophysical data and run sufficient statistical analyses, to be able to build experience from one field to the other, and even compare fields world-wide?

- If you consider that this database can be used in other contexts than in Mexico, it would be very valuable to elaborate a bit. How can a given petrophysical dataset be used to better understand reservoir behavior? To interpret geophysical data at other places?

In general, I think this is a very important and interesting discussion and your paper is a great opportunity to foster it (with a section in the discussion section?).

Regardless the answer to the question above, I think it is necessary to put this study more in context with similar studies. It is not the first time that such a massive effort is made in the context of high-enthalpy geothermal exploration. I can see that you refer to the P3 database made in the frame of IMAGE project, where the focus was on Iceland and Italy. I think it is critical to expand a bit on the differences and on the coherence between the two projects / databases. Why is this new database necessary after the one in the IMAGE project? How are they complementary? What results from IMAGE have convinced you that making such a database was useful? This would be a useful addition at lines 80-87.

There is also a range of (recent) studies that already use extensive and relevant petrophysical dataset to interpret/calibrate their conceptual models. I think that referring

to them would give more weight to your paper, by emphasizing how useful it is to have petrophysical data to calibrate geophysical data. You can stay in the field of geothermal-related studies or even extend a bit broader to sedimentary context. I have listed below a few studies that I find particularly relevant.

a. Suggestion of additional references

References to similar studies, complementary data, and successful application of petrophysical calibration of geophysical data are missing in the introduction and/or discussion. Suggestions below.

“Imaging the magmatic system beneath the Krafla geothermal field, Iceland: A new 3-D electrical resistivity model from inversion of magnetotelluric data”

–> Interpret MT inversions at geothermal fields using petrophysical calibration (especially temperature dependent measurements).

“New Conceptual Model for the Magma-Hydrothermal-Tectonic System of Krafla, NE Iceland” https://www.mdpi.com/2076-3263/10/1/34

–> Shows how conceptual models are regularly updated in light of new petrophysical understandings

Study related to both IMAGE and GEMEx projects: “Electrical resistivity tomography and time-domain induced polarization field investigations of geothermal areas at Krafla, Iceland: comparison to borehole and laboratory frequency-domain electrical observations” https://academic.oup.com/gji/article-abstract/218/3/1469/5497301

–> Interpret DC/IP inversions based on petrophysical measurements on core samples at the exact same site. Discussion on upscaling with in particular comparison of samples to borehole logging and analyses of in-situ versus laboratory temperature differences.

“A probabilistic geologic model of the Krafla geothermal sys-

tem constrained by gravimetric data" https://geothermal-energy-journal.springeropen.com/articles/10.1186/s40517-019-0143-6

–> Statistical analysis of the link lithology versus density, and use to interpret gravity data. Could be cited around l. 79.

"Subsurface imaging of water electrical conductivity, hydraulic permeability and lithology at contaminated sites by induced polarization" https://academic.oup.com/gji/article/213/2/770/4816733

–> Lithology and permeability characterization using petrophysical calibration based on extensive laboratory database measured at a different area (German sediments in the laboratory used to interpret geophysics in Denmark).

You are saying in the introduction that data are distributed in different places (l.72-79), which makes their use complicated. But if this database is intended to be used in a more general manner than just in this project in Mexico, then there needs to be a (short) section on other similar database and how they can be combined. It could be in the discussion as well. I would also add references, either in the introduction (near l.72-79) or in the discussion, to data collection presented in separated papers or PhD thesis, provided that the data collection is significantly large and well-presented and contains consistent data to be comparable to your database, of course. That way the reader will know where to find complementary information, if he needs, e.g. in the IMAGE database or in other articles. A few suggestions below.

"Modification of the magnetic mineralogy in basalts due to fluid–rock interactions in a high-temperature geothermal system (Krafla, Iceland)" (see Table A1)

https://academic.oup.com/gji/article/186/1/155/697067

In relation to IMAGE project and to geophysical interpretations above: "Electrical conductivity of Icelandic deep geothermal reservoirs up to supercritical conditions: Insight from laboratory experiments" (numerous tables and empirical laws for extrapolation)

https://www.sciencedirect.com/science/article/pii/S0377027317304092?casa_token=-tRHyFGSwmcAAAAA:Dmv27QlGdotqHm7Pp-GzsKgyoGSPmlFq70VKAq1w6rgWdT5n45q5OFh4eDYXksNHhwAf0

Also in relation to IMAGE project and to geophysical interpretations above:" The role of smectites in the electrical conductivity of active hydrothermal systems: electrical properties of core samples from Krafla volcano, Iceland"

https://academic.oup.com/gji/article-abstract/215/3/1558/5076040

b. Structure of the paper

The abstract could be shortened. I don't think the details on number and locations of samples are necessary, the two paragraphs l. 41 to l.53 could be significantly reduced.

The discussion is a bit overwhelming and seems to mix results and conclusions. It could be re-organized in different sub-sections, e.g.

(i) how is this database useful (see detailed questions suggestions above –> I think this section should be greatly enhanced and developed compared to how it is now)

(ii) what are the limitations and pitfalls and how to overcome them. More clarity in the discussion would help the reader feel more confident about in which contexts it is "safe" to use the database and in which contexts these data should be treated more carefully.

c. Materials and Methods - Electrical measurements

l. 442 "were executed in a similar way with an impedance spectrometer" –> you present three different types of electrical measurements, they are not that similar. Especially the "estimation from electrical resistivity tomographies performed in the sampling areas" l. 440. This is not state-of-the-art practice, so I would be careful here. How do you evaluate if the different types of measurements can be safely merged together? Have you tried different categories of measurements on the same samples? Alternatively, the different methods could be clearly presented in the database (different columns /

specific column for different methods). It is not clear to me where the “field samples” using ERT values are shown? Does this mean that people will be using ERT values to calibrate future MT inversion? Shouldn’t that rather be handled by joint inversion? ERT has its own issues (equivalences, DC static shift, convergence of inversion) so the value of these data will strongly depend on how the ERT was carried out (electrode spacing, geometric factor, current injected, presence of background noise, misfit of the inversion). It can be a good idea to include electrical measurements from ERT in the database, especially if you have a lot of ERT surveys and few samples in the corresponding area, but they should be much more clearly explained. As a potential user of your database, I wouldn’t use ERT values for calibration if I don’t know how they have been obtained.

l. 449 “The error of measurements at dry conditions is 1.5% on average” –> how did you calculate it? It should be explained clearly. It is far from trivial to estimate this uncertainty. See examples below on the different sources of systematic errors and uncertainties in electrical measurements on rock samples.

http://eprints.whiterose.ac.uk/103298/

https://academic.oup.com/gji/article-abstract/215/3/1558/5076040

https://onlinelibrary.wiley.com/doi/full/10.1002/nsg.12069

c. Section 6 “Status of the database”

This section presents a lot of numbers, hard to follow, maybe a table would be better?

d. Discussion

l. 600 “The high number of analyzed plugs and samples enables detailed statistical and spatial geostatistical analyses on different 600 scales (plug, sample, outcrop, formation or model unit), spatial evaluation of the results in 2D or 3D or the validation of different analytical methods.”

–> Electrical measurements were only made on 50 samples (Table 2), compared to 1000-1500 samples for all other properties. Is it sufficient for statistical analysis? Does it mean that this database has some specific limitations for interpreting MT/TEM inversions? If so, you should clearly state it and suggest how to overcome this issues (e.g. use data from IMAGE dataset or other studies mentioned above, where more than 100 different samples are presented per study, with all relevant mineralogical and petrophysical properties).

–> Why “only” 50 samples have electrical measurements? Some specific issues/limitations, maybe too time-consuming or expensive? I think it is totally normal to have limitations but it is important to the reader to understand the causes of this huge difference.

–> This is even more important given that some (how many??) of these 50 measurements are actually inferred from ERT and not direct laboratory measurements.

l. 608 “So far, only a few geothermal exploration studies in volcanic settings provide rock properties analyzed on [. . .] reservoir core samples”.

–> There are more than few available. See references above and many other references. I think you should re-consider the structure and arguments of the discussion: see my other comments above. As I see it, the added value of your study is to provide a ready-to-use dataset for a specific exploration case + show and discuss how it can be used / not used in the future. Providing additional physico-chemical properties of volcanic rocks is of course a valuable side-effect. But it would not be sufficient as a single aim, because there are already a lot of data available, in particular in relation to IMAGE project.

l. 641 “In some cases, intensive hydrothermal alteration prevents a clear identification of the original rock type and correlation to equivalent units in the outcrops”

–> Good that you mention this limitation. What percentage of cases?

e. Figure 3 Electrical resistivity measurements are not part of the workflow figure. Why?

3. Technical corrections

- “Data” is a plural –> check throughout the manuscript

- “Aim at verb-ing” –> check

- Use of present/past –> try to choose one tense and keep it consistently. As it is now it makes the text hard to digest.

- Try to not overload sentences with adjectives, it makes it more difficult to read and slows down the flow. E.g. l. 611 “petrophysical and rock mechanical data was used for various different purposes.”

Some sentences are difficult to understand, sometimes lacking a verb. Some examples below: - L. 644 “Current studies including detailed petrographic analyses and ICP-MS measurements, aiming to provide a better description and sample classification (Weydt et al., 2020, in prep.).” - L. 657 (which concept?) - L. 602 “Whenever possible, all parameters were analyzed on each plug allowing the identification of statistical and causal relationships between the parameters improving the accuracy of geostatistical predictions” –> this is hard to follow, maybe split the sentence?

Please also note the supplement to this comment:
https://essd.copernicus.org/preprints/essd-2020-139/essd-2020-139-RC2-supplement.pdf

---

Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2020-139, 2020.