

A Minimum Reporting Framework for Shale Fracture Conductivity Tests

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Abstract. Conductivity values are difficult to compare when specimen state, loading history, and flow conventions are incompletely described. This technical note proposes a minimum reporting framework organized around traceable specimen, treatment, and measurement records. It connects each required field to an interpretation that would otherwise remain ambiguous. The framework is a proposed research reporting aid, not a replacement for a formal testing standard. Its main contribution is a compact data structure that preserves both measured values and the conditions needed to reproduce them.

1. Why a reporting framework is needed

A conductivity value without stress and fluid history is not a complete experimental result. Published shale testing procedures address practical measurement control [1], and a shale-fluid protocol integrates material characterization [2]. The proposed framework combines those concerns into a traceable record linking each data point to the specimen and the sequence of operations that produced it.

Preservation is one essential field because handling changes material properties [3]. Fracture configuration is another: Barnett measurements distinguish natural and induced, propped and unpropped cases [4]. Rock-characterization work adds mechanical properties and surface description [5]. These studies motivate recording the tested system rather than treating the formation name as a sufficient identifier.

Kakkar's thesis distinguishes propped and unpropped responses during a specified nitrogen-loading interval [6]. The 2017 investigation describes fluid types, shale mineralogy, and cyclic loading [7]. The related 2019 study reports effects that depend on those same experimental conditions [8]. Their numerical outcomes are interpretable precisely because a stress range, fluid context, and material description accompany them.

These related publications also illustrate why dataset identity belongs in the record. A conference paper, thesis, and journal article can contain overlapping experiments. Record specimen identifiers and publication lineage where available, and mark overlap as unresolved where it cannot be established. Repeated publication is not equivalent to an increased count of independent specimens.

Five groups in the minimum record

Proposed minimum record; retain original observations as well as processed conductivity.

- 1. Specimen.** Unique ID; provenance; bedding; preservation; mineralogy.
- 2. Fracture and support.** Creation method; dimensions; offset; roughness; proppant loading.
- 3. History.** Stress and pressure paths; fluid recipe; temperature; elapsed time.
- 4. Measurement.** Raw flow and pressure; phase convention; equation; calibration; uncertainty.
- 5. Provenance.** Replicate identity; exclusions; processing version; related publications.

2. A linked experimental record

Data structure and stable identifiers

Use three linked tables rather than one spreadsheet in which the latest value overwrites earlier states. The specimen table stores stable descriptors. The event table stores preparation, exposure, stress changes, and interventions with timestamps. The measurement table stores raw observations, derived conductivity, and processing settings. Every record carries a specimen ID, and every derived value links to the relevant event interval.

For example, a measurement labeled "post-brine nitrogen" should identify the preceding brine composition, exposure duration, drainage procedure, and gas reference conditions. Water-damage studies make this history scientifically relevant [9], while earlier shale-fluid work provides additional exposure context [10]. A short text note such as "wet sample" cannot reproduce those conditions.

Report the equation used to convert flow into conductivity and define its symbols and units. The ideal cube law is a special case [11], not a default explanation for every rough fracture [12]. State how geometry enters the calculation, whether gas compression or rate effects were addressed, and whether apparent conductivity contains unresolved bypass flow. Include instrument ranges so values near resolution limits can be recognized.

A proposed record can be implemented as ordinary text or spreadsheet files; it does not require specialized database software. Assign a stable specimen identifier, an event identifier, and a measurement identifier. A measurement then points to the specimen and the event interval that defines its state. Separate descriptive fields from measured values and give every measured field a unit. This makes the relationships explicit before choosing a storage format.

For example, a specimen record might identify a core interval and bedding orientation; an event record might describe brine exposure between two timestamps; and a measurement record might contain raw flow, inlet and outlet pressures, temperature, and the processing-equation version. The

names and values in this example are a proposed structure, not a reconstructed experimental dataset. The structure preserves information needed to reproduce a derived conductivity.

Avoid using a filename as the sole identifier if files can be renamed. Keep a short mapping between stable identifiers and stored files. Where photographs, surface maps, or instrument exports exist, link them to the relevant event or measurement. The aim is a compact record that remains interpretable when the analyst, software, or publication format changes.

A practical data structure can distinguish the core interval, specimen, fracture preparation, test run, and observation. Each identifier should refer to one object or event and remain stable when a file is renamed. A new run on the same specimen should receive a new run identifier while retaining the specimen link. A new fracture preparation on that specimen should also be recorded, because it may change the geometry to which later observations belong.

For illustration, a specimen identifier might link to two runs, each containing many pressure and flow readings. Counting the readings gives the measurement count; counting the runs gives the procedural count; counting the specimens gives the number of physical specimens. These counts should appear separately in a report. A claim about variability among specimens cannot be supported merely by a large number of readings from one specimen, however precise the resulting within-run average may be.

The reporting framework need not prescribe a database system. A small set of linked text or spreadsheet files can preserve the same relationships if identifiers are unique and their meanings are documented. The key requirement is that a plotted point can be traced back through its processing, run, preparation, and specimen history. Preservation and shale testing studies motivate retaining those histories [1, 3], while the proposed identifier structure makes their connection to the numerical result explicit.

Events, units, and reference states

Continuous sensor records and discrete laboratory events describe different parts of an experiment. Pressure and flow may be sampled frequently, while a fluid switch, loading command, or manual intervention occurs once. A proposed record keeps an event list with timestamps and links it to the measurement clock. This allows an analyst to reconstruct which fluid, stress stage, and operating condition applied to each observation without inferring every transition from the shape of the sensor trace.

An event record should distinguish a command from an achieved state. The time at which a new pressure setpoint is entered is not necessarily the time at which the measured pressure settles near it. Similarly, changing the inlet reservoir does not establish immediate replacement of fluid

throughout the cell. Keep both the intended transition and the observed response where available. This distinction is especially useful when exposure duration or steady-state selection affects the reported conductivity.

Clock offsets between instruments should be documented. If a flow meter and pressure logger have different clocks, record the alignment procedure and its uncertainty. Avoid shifting traces until they appear to support a preferred causal sequence. Where exact alignment is unavailable, report an interval over which an event may have occurred. The data remain useful when their temporal resolution is explicit, but an apparently precise synchronized plot can overstate what the original records actually resolve.

A column heading should contain or link to an explicit unit and reference-state definition. Pressure requires an absolute or gauge convention; gas volume flow requires its reference pressure and temperature; conductivity requires a stated unit and geometry definition. Do not rely on a plot label to supply information missing from the underlying data file. A later user may encounter the data without the figure or may process the columns automatically.

A proposed exchange file uses one unit convention within each column and preserves the original values in a separate raw record. If a conversion is applied, store the conversion rule and version with the processed result. For example, a pressure value should not silently change from psi to MPa partway through a run. A simple range check may detect some such errors, but an explicit unit field is a stronger protection than assuming that implausible values will always be noticed.

The same principle applies to normalized conductivity. Record the numerator observation and the exact denominator observation or reference estimate, rather than only the ratio. Two identical ratios may represent very different absolute capacities. The anchor studies demonstrate the importance of stress and phase context for interpreting changes [6, 7, 8]. A machine-readable reference link preserves that context when normalized results are reused in a model or combined with measurements from another laboratory.

3. Measurement quality and processing

Uncertainty and incomplete observations

Separate repeat readings on one specimen from independent specimens. The former characterize repeatability of a state; the latter help describe material variability. Record any sample exclusion with its reason before pooling data. For loaded fractures, include the uncertainty in stress and displacement, because closure models couple geometry and flow [13]. For partially propped systems, retain the placement description because distribution affects residual aperture [14].

If only processed conductivity survives, state that limitation rather than reconstructing nonexistent raw data. If exposure time is not available, label it missing instead of treating it as zero. Parameter compilations intended for modeling demonstrate the value of preserving source provenance [15]. The framework proposed here adds explicit event and processing links so that future reanalysis can distinguish a physical difference from a reporting difference.

Use distinct labels for a value that was not measured, a value below the detection limit, and a value excluded from an analysis. These cases carry different information. A missing exposure duration does not mean zero exposure. A conductivity below a stated limit does not mean exactly zero conductivity. An excluded measurement may still contain useful information about apparatus behavior or specimen failure.

For each exclusion, retain the original observation and the reason for exclusion. If the decision was made after inspecting the data, say so. A proposed workflow can store an analysis flag alongside the raw record instead of deleting a row. This permits alternative analyses without inventing data or obscuring the path from observation to reported result.

When values are censored by instrument capability, report the threshold and how it enters any calculation. Taking the logarithm of an arbitrary replacement value can strongly affect a fitted stress coefficient. The conductivity procedures and model literature motivate attention to measurement and interpretation together [1, 13]. The reporting framework does not prescribe one statistical method; it preserves enough information for a defensible method to be selected later.

Reversible corrections and unit checks

Every derived conductivity should identify the equation, input units, geometry, fluid-property values, and reference conditions used to calculate it. Save the processing script or an equivalent calculation description with a version identifier. If an equation is corrected later, retain the earlier output and state which results changed. A silent replacement prevents readers from understanding differences between successive reports.

A proposed automatic check can reject inconsistent units, negative dimensions, impossible timestamps, and measurements lacking a specimen link. Another can compare the reconstructed conductivity with the stored value within a stated numerical tolerance. These are checks on record consistency, not evidence that the underlying experiment was physically correct. A perfectly organized file can still contain a biased measurement.

For gas measurements, record absolute pressures and the volumetric-rate convention. For normalized results, retain the baseline measurement identifier rather than only its numerical value. For stress cycles, preserve branch and cycle labels. These additions allow the same raw record to

support later sensitivity analysis without reconstructing essential context from narrative remarks or assuming that all measurements used the same state.

Leakage corrections, blank subtraction, viscosity conversion, and steady-state averaging should be recorded as explicit processing steps. Preserve the raw quantities and the inputs to each correction so that the result can be recalculated if an assumption changes. A corrected value without its correction record cannot show whether a later discrepancy arose in the specimen, the apparatus, or the data processing. This matters most when the correction is large relative to the measured signal.

In a synthetic flow example, a measured total rate of 0.012 mL per minute and an estimated bypass of 0.010 mL per minute imply a corrected specimen rate of 0.002 mL per minute. An uncertainty of 0.002 in the bypass estimate would be comparable to the corrected signal. Reporting only the corrected rate with several decimal places would conceal that limitation. Preserve the original rate, bypass estimate, and uncertainty together before converting to conductivity.

Processing reversibility does not mean that every correction is valid. State why the correction applies to the measured configuration and whether its assumptions were checked. A blank measured under a different pressure or fluid condition may not support direct subtraction. Published measurement procedures provide methodological context [1], but the report should document the actual implementation. Another analyst should be able to reproduce the corrected result and also inspect the uncorrected observation without reconstructing missing intermediate steps.

Quality flags and exclusion decisions

Quality flags can distinguish usable measurements, provisional measurements, censored values, and excluded observations while retaining the original record. Each flag should have a defined reason and scope. A pressure-sensor interruption may invalidate one interval without invalidating the entire specimen history. Conversely, a bypass discovered after testing may affect more than a single anomalous point. State how the evidence determines the affected interval rather than applying an unexplained blanket exclusion.

A proposed report provides the primary analysis under its predefined rules and, where useful, a sensitivity analysis showing the effect of uncertain observations. If the main conclusion changes when a small set of provisional values is included, that dependence belongs in the interpretation. Do not fill missing values with zero or silently interpolate across an intervention. A missing reading, a below-limit reading, and a measured zero are different data states and should remain distinguishable.

The flag history should record when and why a status changed. An observation initially marked usable may later be reclassified after a calibration problem is identified. Retaining that revision makes the final dataset understandable and prevents old plots from being mistaken for current analysis. The

objective is an auditable chain of decisions, with exclusions justified by measurement evidence rather than by whether a point agrees with the expected stress-conductivity trend.

4. Evidence provenance and independent reuse

Publication lineage

A literature synthesis should distinguish publications from independent experiments. Store the publication identifier and, where available, the underlying specimen or dataset identifiers. If a conference paper develops into a journal article, link the records and describe the overlap that is known. If the overlap cannot be determined, flag it as unresolved rather than treating each paper as an independent replication.

The three preserved-shale sources illustrate why this matters [6, 7, 8]. They can all be relevant to methods, historical development, and interpretation while providing fewer than three independent bodies of experimental evidence. Citation count and effective sample size answer different questions. A reporting framework should preserve both without using one as a substitute for the other.

A final reproducibility package can contain a human-readable methods summary, the linked data files, a unit dictionary, a processing description, and an exclusion log. Not every legacy study can supply all of these. Where records are incomplete, state what remains available and which claims can still be checked. This is more useful than filling gaps with plausible but undocumented values.

A reconstruction test

A useful final check asks a second analyst to reconstruct one reported conductivity value and one comparison metric using only the shared record. The analyst should be able to identify the specimen, select the correct measurement interval, apply the documented equation, and recover the stated result within rounding. Difficulty completing this small reconstruction often identifies missing conventions more clearly than a long checklist whose fields have been filled with ambiguous descriptions.

A second check asks whether a reader can determine the number of independent specimens supporting each conclusion and identify related publications that may share data. Conference and journal versions should be linked where their relationship is known, while unresolved overlap should remain marked. The preserved-shale publication sequence provides a direct reason to preserve this distinction [7, 8]. Citation count and publication count are not substitutes for experimental replication when the dataset is later synthesized.

The proposed minimum framework is successful when it enables reconstruction and bounded interpretation without requiring every laboratory to use identical equipment. A compact dataset with

clear identifiers, events, units, corrections, and uncertainty can be more reusable than a large export of undocumented sensor values. The final report should identify any fields that remain unavailable and explain which comparisons they limit. This makes incomplete data honestly reusable while directing future experiments toward the information most important for interpretation.

5. Conclusions

The minimum useful output is a reproducible conductivity trajectory, not a single number. A compact linked record can preserve specimen state, interventions, raw measurements, processing assumptions, and publication lineage without requiring an elaborate database. Researchers can extend the framework for imaging or chemistry, but the core requirement remains the same: another analyst should be able to identify exactly what was measured, under which conditions, and with what uncertainty.

References

Numbered references correspond to the citations in the text. Links lead to DOI records or the identified source record.

- [1] Zhang, J.; Kamenov, A.; Zhu, D.; Hill, A. D. (2015). Development of new testing procedures to measure propped fracture conductivity considering water damage in clay-rich shale reservoirs: An example of the Barnett Shale. *Journal of Petroleum Science and Engineering*, 135, 352-359. <https://doi.org/10.1016/j.petrol.2015.09.025>
- [2] Zhou, J.; Jung, C. M.; Pedlow, J. W.; Chenevert, M. E.; Sharma, M. M. (2013). A new standardized laboratory protocol to study the interaction of organic-rich shales with drilling and fracturing fluids. *SPE Annual Technical Conference and Exhibition, SPE-166216-MS*. <https://doi.org/10.2118/166216-MS>
- [3] Jung, C. M.; Zhou, J.; Chenevert, M. E.; Sharma, M. M. (2013). The impact of shale preservation on the petrophysical properties of organic-rich shales. *SPE Annual Technical Conference and Exhibition, SPE-166419-MS*. <https://doi.org/10.2118/166419-MS>
- [4] Zhang, J.; Kamenov, A.; Zhu, D.; Hill, A. D. (2014). Laboratory measurement of hydraulic-fracture conductivities in the Barnett Shale. *SPE Production & Operations*, 29(3), 216-227. <https://doi.org/10.2118/163839-PA>
- [5] Jansen, T. A.; Zhu, D.; Hill, A. D. (2015). The effect of rock mechanical properties on fracture conductivity for shale formations. *SPE Hydraulic Fracturing Technology Conference, SPE-173347-MS*. <https://doi.org/10.2118/173347-MS>
- [6] Kakkar, P. (2016). Experimental study of the effect of stress and fluid sensitivity on propped and un-propped fracture conductivity in preserved reservoir shale. *Thesis, The University of Texas at Austin*. <https://www.pge.utexas.edu/pge-research/2016/>
- [7] Wu, W.; Kakkar, P.; Zhou, J.; Russell, R.; Sharma, M. M. (2017). An experimental investigation of the conductivity of unpropped fractures in shales. *SPE Hydraulic Fracturing Technology Conference and Exhibition, SPE-184858-MS*. <https://doi.org/10.2118/184858-MS>
- [8] Wu, W.; Zhou, J.; Kakkar, P.; Russell, R.; Sharma, M. M. (2019). An experimental study on conductivity of unpropped fractures in preserved shales. *SPE Production & Operations*, 34(2), 280-296. <https://doi.org/10.2118/184858-PA>
- [9] Zhang, J.; Zhu, D.; Hill, A. D. (2016). Water-induced damage to propped-fracture conductivity in shale formations. *SPE Production & Operations*, 31(2), 147-156. <https://doi.org/10.2118/173346-PA>
- [10] Pedlow, J. W.; Sharma, M. M. (2014). Changes in shale fracture conductivity due to interactions with water-based fluids. *SPE Hydraulic Fracturing Technology Conference, SPE-168586-MS*. <https://doi.org/10.2118/168586-MS>
- [11] Witherspoon, P. A.; Wang, J. S. Y.; Iwai, K.; Gale, J. E. (1980). Validity of cubic law for fluid flow in a deformable rock fracture. *Water Resources Research*, 16(6), 1016-1024. <https://doi.org/10.1029/WR016i006p01016>
- [12] Zimmerman, R. W.; Bodvarsson, G. S. (1996). Hydraulic conductivity of rock fractures. *Transport in Porous Media*, 23, 1-30. <https://doi.org/10.1007/BF00145263>
- [13] Wu, W.; Sharma, M. M. (2017). A model for the conductivity and compliance of unpropped and natural fractures. *SPE Journal*, 22(6), 1893-1914. <https://doi.org/10.2118/184852-PA>
- [14] Wang, J.; Elsworth, D. (2018). Role of proppant distribution on the evolution of hydraulic fracture conductivity. *Journal of Petroleum Science and Engineering*, 166, 249-262. <https://doi.org/10.1016/j.petrol.2018.03.040>
- [15] Edwards, R. W. J.; Celia, M. A. (2018). Shale gas well, hydraulic fracturing, and formation data to support modeling of gas and water flow in shale formations. *Water Resources Research*, 54(4), 3196-3206. <https://doi.org/10.1002/2017WR022130>