

Connecting Laboratory Conductivity Measurements with Diagnostic Fracture Injection Tests

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Abstract. Laboratory conductivity tests and diagnostic fracture injection tests interrogate different systems through different observables. The laboratory measures controlled flow through a specimen; a DFIT records a field pressure transient from which properties are inferred using a model. This note proposes a cross-scale comparison workflow that keeps stress, compliance, geometry, and fluid history explicit. Its main contribution is an identifiability checklist: agreement should be judged between compatible forward predictions, rather than by directly equating a core-scale conductivity with a field-inferred parameter.

1. Observables and laboratory constraints

A laboratory test uses measured flow and pressure difference with a specified geometry and flow equation to infer specimen conductivity. A DFIT records pressure during and after an injection sequence. Wang and Sharma propose estimating unpropped conductivity and compliance from such transients [1]. The field inference therefore depends on the assumed evolution of fracture geometry, closure, fluid exchange, and system storage.

Compliance describes deformation per change in loading, whereas conductivity describes hydraulic transmission. These quantities can be related through a model but are not identical observables. Rough-contact models explicitly examine their connection [2], and non-local closure modeling adds interactions among surface regions [3]. A successful fit to pressure should not be interpreted as a direct image of contact geometry.

Kakkar's nitrogen-loading results provide a condition-specific example of stress sensitivity and incomplete return-state recovery [4]. The 2017 investigation adds fluid exposure and cycling in preserved shale [5], and the related 2019 paper describes the resulting conductivity impairment [6]. These records can motivate the range and form of laboratory-informed hypotheses, while their overlap prevents treating them as three independent field constraints.

Barnett conductivity measurements provide another laboratory comparison [7]. Preservation studies establish why the tested material state must be known [8], and water-damage experiments establish the relevance of exposure history [9]. A dry or differently conditioned specimen is not automatically a surrogate for a recently injected field fracture, even if both originate from the same formation.

Aligning laboratory and field descriptions

Proposed laboratory-to-DFIT comparison checklist.

Stress and geometry. Pair laboratory applied traction and pore pressure with local stress and pressure evolution in the field model. Pair known specimen dimensions with assumed or constrained fracture extent.

State and observable. Pair preservation and fluid sequence with injection and post-injection history. Keep laboratory flow and differential pressure distinct from the field observable, pressure versus time.

Inference. Compare equivalent specimen conductivity with a model-dependent field parameter range.

2. Building a compatible forward comparison

2.1 Defining the field pressure record

A field pressure trace is a measurement at a specified location, processed through a specified acquisition system. A proposed laboratory-to-field comparison begins by identifying that location, the pressure convention, the time origin, and any corrections applied before interpretation. Preserve the injection schedule and the transition to shut-in as recorded. These details define the observation the model must predict and prevent an ambiguous data transformation from being absorbed into a fitted conductivity or compliance parameter.

If the interpreted pressure differs from the directly recorded pressure, state the transformation and its inputs. A calculated downhole pressure, for example, should be distinguishable from a directly measured value in the dataset. Retain the uncertainty associated with the transformation rather than treating the processed trace as exact. The proposed comparison does not prescribe a universal correction; it requires the chosen observation model to be explicit enough that another analyst can reproduce it.

Wang and Sharma's DFIT-based conductivity and compliance approach supplies a relevant inverse-model precedent [1]. A new application should identify the version and assumptions actually used rather than invoke DFIT interpretation as a single fixed procedure. The laboratory evidence can constrain candidate fracture behavior, but it cannot repair an undefined field observation. Establishing the pressure record is therefore a prerequisite to deciding whether a disagreement concerns measurement processing, boundary conditions, or fracture physics.

2.2 Observable predictions and parameter meaning

A laboratory-to-field comparison should begin with what the field instrument observes: pressure as a function of time under a stated injection and shut-in history. The forward model maps assumptions about geometry, storage, fluid exchange, and mechanical-hydraulic response into that observable. Laboratory conductivity then constrains one part of the mapping rather than becoming a direct substitute for the measured pressure record.

The DFIT method cited in this article links pressure-transient behavior with fracture conductivity and compliance [1]. That methodological connection motivates the comparison; it does not remove the need to state the forward-model assumptions. A result inferred using one geometry or storage description may not be numerically equivalent to a parameter inferred using another.

A proposed report should show the family of pressure responses compatible with the selected laboratory trajectories and independent field constraints. If the observed response falls outside the family, examine both the laboratory transfer assumptions and the field model. Agreement is evidence of consistency within the tested model class, not proof that the underlying geometry or conductivity function has been uniquely identified.

Two models may both contain a parameter called fracture conductivity while assigning it different spatial or temporal meanings. One may use a uniform fracture value, another an effective connection between regions, and a third a pressure-dependent local law. A proposed comparison writes the role of the parameter in the forward equations before transferring a laboratory estimate. Similar units and names are necessary checks, but they do not establish that the parameters represent the same physical quantity.

A laboratory trajectory can be used to generate several candidate pressure-dependent laws under a stated scaling assumption. Each candidate is then passed through the same field forward model to predict the measured pressure record. Compare those observable predictions with the field data while keeping geometry and other assumptions visible. This route makes the transfer testable: the question becomes whether the laboratory-informed behavior is compatible with the pressure trace under the specified model, rather than whether two fitted numbers happen to agree.

Contact models connect mechanical and hydraulic response [2, 3], and the preserved-shale studies document stress and exposure dependence [4, 5, 6]. Together they motivate a state-aware transfer. They do not establish a unique mapping from a core specimen to a field fracture. The proposed workflow should retain alternative mappings where the scale relationship is unresolved and show which of them the field observation can actually distinguish.

2.3 State and scale alignment

The shared stress interval should be identified before comparing laboratory and field descriptions. A curve measured at one initial state and along one loading branch may not represent a recently injected fracture following another history. Preserve the distinction between total traction, pore pressure, effective stress, stiffness, and compliance. Similar units or correlated trends do not make these quantities interchangeable.

A proposed transfer record can list the laboratory specimen state, the field state being represented, and the assumptions connecting them. Preservation and fluid-exposure studies motivate attention to material history [8, 9], while rough-contact and joint-mechanics work motivates the mechanical-hydraulic link [2, 10]. The record should also state which aspects of spatial heterogeneity are omitted.

If laboratory data are used as a prior constraint, distinguish measured variability from analyst-selected widening intended to account for scale mismatch. If they are used only to select candidate functional forms, say that instead. These uses provide different amounts of information. Keeping them separate prevents a broad qualitative analogy from being presented as a precise quantitative calibration.

3. Identifiability and competing solutions

3.1 Illustrative inverse problems

In a highly simplified lumped model, let a pressure difference decay through a conductance G from a storage capacity S , giving a characteristic time $\tau = S/G$. A measured τ alone cannot determine both S and G . Doubling both leaves τ unchanged. This is a generic illustrative inverse problem, not a DFIT interpretation equation or a reproduction of the cited method.

The example shows why a laboratory constraint can be useful without uniquely solving the field problem. Independent information about storage, fracture dimensions, or mechanical response can narrow admissible combinations. Conversely, assigning a precisely measured laboratory C to the field while leaving geometric factors unconstrained can create a misleading appearance of parameter certainty.

The ideal cube-law relation gives one possible aperture-flow connection [11], but rough-fracture theory introduces additional geometric dependence [12]. Joint mechanics provides a broader account of stress-coupled deformation [10]. These sources support keeping the conversion from mechanical response to hydraulic response explicit, rather than assuming that one stiffness estimate determines conductivity independently of surface structure.

Extend the illustrative relation $\tau = S/G$ by assigning a measured time scale of 10 normalized units. The pairs $S = 10$, $G = 1$ and $S = 20$, $G = 2$ both give that time scale. Without another

constraint, the measurement cannot distinguish them. These pairs are hypothetical and the relation is a teaching model, not a DFIT interpretation equation.

Suppose independent information restricts S to the interval 8 to 12 in the same normalized system. Then G is restricted to 0.8 to 1.2 if τ is exactly 10. If τ also has uncertainty, the admissible range widens. For example, allowing τ from 9 to 11 gives bounding ratios of approximately 0.727 and 1.333. This interval is a scenario bound from the selected inputs, not a confidence interval inferred from field data.

The example clarifies the role of an independent constraint: it narrows a family of solutions rather than converting an inverse problem into a direct measurement. A laboratory value can be informative in the same way, provided the transformation from specimen conductivity to field conductance or compliance is explicitly defined and its geometric uncertainty is retained.

3.2 Profiles of acceptable solutions

A single best-fitting parameter set can conceal a broad family of comparably adequate solutions. A proposed diagnostic fixes one parameter, such as a conductivity scale, at successive values and adjusts the remaining allowed parameters at each value. Plot or report the resulting misfit profile and inspect the associated changes in storage, geometry, or exchange terms. A flat region indicates that the selected pressure record does not strongly distinguish those conductivity values within the model.

The procedure should retain physical and independently supported bounds on the other parameters. Allowing an unconstrained storage term to take implausible values can make almost any conductivity appear acceptable. Conversely, fixing an uncertain quantity exactly can make the conductivity estimate appear more precise than the evidence warrants. State which quantities are measured, bounded, fitted, or fixed by assumption and repeat the profile for influential alternative assumptions when the intended conclusion depends on them.

A hypothetical result might permit a tenfold range of conductivity scales while producing similar pressure misfits through compensating storage changes. That selected example would show non-uniqueness in the chosen inverse problem, not a tenfold uncertainty established for a real well. The useful outcome is a diagnosis of the missing constraint. An independent observation of geometry or storage could then be evaluated for whether it narrows the solution family relevant to conductivity.

4. Validation and transfer uncertainty

4.1 Information across the transient

Different parts of a transient can constrain different combinations of model behavior. A proposed analysis should therefore retain the full usable record and state why any time interval is excluded. Fitting only a visually convenient interval may leave the model inconsistent elsewhere. Conversely, forcing one simplified model to reproduce every interval can bias its parameters if the model omits processes relevant to part of the record. The interval selection and model scope should be assessed together.

Compare predictions in the original pressure-time domain as well as in any transformed diagnostic representation. A transformation can make a feature easier to see, but it also changes how measurement errors and smoothing appear. Retain the processing settings and show whether a claimed feature persists under reasonable alternatives. The proposed check is not a replacement for a particular diagnostic method; it is a way to keep that method connected to the underlying observation.

A useful validation strategy fits a declared interval and predicts a withheld interval without retuning. Success supports the model's consistency across those times, while failure identifies an unresolved state or process. It does not establish field-scale conductivity uniquely, because multiple models may pass the same test. Report both the predictive result and the remaining alternatives, especially when a laboratory-derived loading law is being extended through a field transient with a different exposure and stress history.

4.2 Laboratory-informed ranges

A laboratory result should enter field interpretation with its specimen variability, measurement uncertainty, and model-form limitations. If only a few specimens are available, a bounded range may be more transparent than a narrowly specified probability distribution. State whether the range represents observed specimen spread, a fitted parameter interval, or an analyst-selected transfer scenario. These categories contain different information and should not be combined under an unexplained uncertainty label.

The field model can be run across the laboratory-supported alternatives while varying uncertain geometry and storage separately. If the pressure predictions barely change across the laboratory conductivity range, the field record may have little power to refine that parameter under the chosen model. If they change strongly, compare the differences with measurement uncertainty and structural model error. Sensitivity is a prerequisite for inference, but high sensitivity alone does not guarantee uniqueness when other parameters can compensate.

Preservation, fluid exposure, and mineralogical differences also limit transfer [8, 9]. A laboratory sample tested under nitrogen may support a mechanical hypothesis without directly representing a recently water-exposed field fracture. The anchor publications provide evidence for retaining these state distinctions [4, 5, 6]. A useful transfer analysis should explicitly identify which state difference is corrected by a model, bracketed by scenarios, or left unresolved because the necessary measurements are unavailable.

5. A practical comparison and reporting workflow

5.1 Implementation and reporting sequence

First reconcile definitions and units, including whether the reported parameter is conductivity, conductance, stiffness, or compliance. Second define the pressure and stress interval shared by the field interpretation and laboratory tests. Third assemble a family of laboratory-consistent conductivity trajectories rather than a single universal curve. Fourth run the field forward model for that family while varying uncertain geometry and storage. Compare the pressure predictions with observations and report unresolved parameter tradeoffs.

The role of induced unpropped fractures provides a field-context motivation [13], while shale parameter compilations offer a transparent starting point for identifying missing inputs [14]. Such compilations should remain traceable sources of ranges, not substitute measurements for a site. Fluid history and spatial pressure gradients should be included in the uncertainty discussion even when the chosen model cannot resolve them.

First hold the laboratory-informed conductivity family fixed and vary uncertain field geometry and storage. Then vary the conductivity family while retaining the same plausible field ranges. Compare how each group changes the predicted pressure response. This proposed sequence identifies whether the observable is more sensitive to conductivity or to other assumptions over the interval being interpreted.

Next examine whether different parameter combinations remain observationally indistinguishable within the measurement uncertainty. Retain those combinations as an admissible set rather than reporting only the best-fitting one. If a second independent observation is available, test whether it reduces the set. Additional observations are valuable when they constrain a different aspect of the model, not merely when they add more points to the same unresolved trend.

The final report should include the forward model, input histories, observation interval, parameter ranges, and unresolved tradeoffs. A satisfactory fit should be described as conditional consistency. The proposed workflow strengthens the connection between laboratory studies and DFIT interpretation by making the transfer and inverse assumptions

reviewable, while avoiding a claim that one core-scale conductivity value uniquely determines a field fracture system.

5.2 A testable cross-scale claim

A defensible conclusion states the level of agreement achieved. The laboratory behavior may be qualitatively consistent with the direction of the field response, quantitatively compatible with a family of forward predictions, or necessary to reproduce an observation within a restricted model class. These are progressively stronger claims. Do not describe compatibility as unique identification, and do not describe a fitted field parameter as an independent validation if laboratory information was already used to constrain that parameter.

A proposed final comparison includes a deliberately different candidate, such as a stress-insensitive conductivity law, when physically meaningful for the stated test. If both candidates reproduce the field record similarly, the record has not demonstrated the need for stress dependence in that application. If they diverge, examine whether the preferred model succeeds in withheld observations and whether the difference can instead be absorbed by another uncertain process. This makes the claim falsifiable within the available evidence.

The most useful next step follows from the unresolved distinction. It may be a better field pressure record, an independent geometry constraint, a laboratory test using the relevant fluid history, or a loading cycle that discriminates competing constitutive laws. The combined workflow then serves a concrete purpose: narrowing the set of compatible fracture descriptions. It does not require laboratory and field estimates to collapse to one apparently precise number before their relationship can be scientifically informative.

6. Conclusions

Laboratory tests can constrain plausible field behavior, and DFIT analysis can test whether those constraints are consistent with observed transients. The comparison is strongest when made through an explicit forward model with compatible definitions and state variables. Report parameter ranges and tradeoffs rather than equating one laboratory value with a unique field estimate. This note supplies a comparison framework and no new DFIT interpretation or field dataset.

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

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