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Äspö Hard Rock Laboratory

TRUE Block Scale Project

Generalized dimension analysis of build-up and pressure interference tests

Thomas Doe

Golder Associates Inc.

October 2002

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel +46 8 459 84 00
Fax +46 8 661 57 19

Äspö Hard Rock Laboratory

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Abstract

This report reviews analysis of well test data from piezometer withdrawal intervals and pressure interference responses during the TRUE Block Scale tracer testing program. The analyses rely on transformations of the pressure derivative curves for transmissivity and distance, the pressure derivative maps and the variation of the semi-logarithmic slope of pressure responses with time. The slope of the semi-logarithmic diagram, along with the flow rate, defines transmissivity; hence the pressure derivative indicates the change of transmissivity with time. A transformation of time to distance using hydraulic diffusivity and the definition of the radius of investigation allows a mapping of hydraulic properties with distance from the pumping section used in the well tests.

Analyses of the pressure derivative plots show that Structure #20 acts as a single planar feature, perhaps with some local channel flow. This planar structure intersects a more conductive structure, that is an order of magnitude more transmissive, about 100-200 metres from the core of the TRUE Block Scale borehole array. This more conductive feature is likely one of the major conductive structures of the Äspö Hard Rock Laboratory, either NE-2 or EW-1. Similar behaviors in the pressure derivative are observed for tests in Structure #13, although with lower transmissivity.

Sammanfattning

Föreliggande rapport behandlar analys av hydrauliska testdata från pumpsektioner liksom av tryckresposer från interferenstester genomförda som en del av spårförsöksprogrammet i TRUE Block Scale-projektet. De genomförda analyserna utnyttjar transformationer av tryckderivatan för bestämning av transmissivitet och avstånd, plottar av tryckderivatan samt variationen i tryckderivatan med tiden. Lutningen av tryckderivatan och pumpflödet ger transmissiviteten; varur följer att tryckderivatan ger förändringen av transmissiviteten med tiden. En transformation av tid till avstånd, med utnyttjande av den hydrauliska diffusiviteten och definitionen på influensavstånd, möjliggör kartläggning av de hydrauliska egenskaperna som funktion av avståndet från pumpsektionen.

Analys av plottar av tryckderivatan visar att Struktur #20 uppträder som en enskild, plan struktur med möjliga inslag av kanalflöde. Denna plana struktur skär en mer konduktiv struktur, en storleksordning mer transmissiv än Struktur #20, cirka 100-200 m från de centrala delarna av den volym som undersöks av de aktuella borrhålen. Denna mer konduktiva struktur är en av de större konduktiva strukturerna på Äspö, antingen Zon NE-2 eller EW-1. Liknande utseende på tryckderivatan noteras även för tester som utförts i Struktur #13 (denna struktur uppvisar dock en lägre transmissivitet).

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1 Introduction

This report presents the results of analyses of well tests in the TRUE Block Scale volume. The main purpose of these interpretations is to provide information on the flow dimensions and boundaries of the conducting features intersected by the borehole. The analyses focus on the longer term tests that were performed as part of the tracer testing program including the pre-tests and the final Phase A series of cross-hole tracer dilution tests.

The question of flow geometry has important implications for the movement of tracers in the TRUE Block Scale volume. How many pathways participate in transport and how much surface area do those pathways provide for fracture-rock interaction? Is the flow along pipe-like channels that would produce geometrically linear flow in hydraulic tests? Is the flow confined to two-dimensional planar features, such as the major features of the TRUE Block hydrostructural model? Is there a three-dimensional network of fractures providing the major portion of flow along the pathways of the tracer tests?

The flow geometry question can be answered in part by careful attention to the geometric information that can be derived from the pressure data produced during the testing. So far in the TRUE Block Scale project, the well test analysis has focussed on methods that assume two-dimensional flow, as in the build-up tests for the KI0025F02 borehole (e.g. Adams, et al, 1999). The hydrostructural model development (Doe, 2001) looked at geometry mainly from the pseudo-steady draw downs at the end of the tests and interference data during drilling and did not use geometric information in the transient data.

A comprehensive look at transient data from the standpoint of flow dimension has not previously been undertaken for the longer-term pumping data that were obtained during the tracer phase of the TRUE Block Scale project. The work presented in this report looks at a sufficient portion of these data to define the flow geometries of the major conductors that were important for the tracer tests, specifically Structure #20 and connecting features, such as Structures #21, #13, and #22. In addition to these analyses, this report also presents a new plotting of the buildup data from KI0025F02 (Adams, et al, 1999) and KI0025F03 (Gentzschein and Ludvigsson, 2001). These tests are short-term (30-minute) tests that do not provide the same distance of coverage as the later tracer tests. They do give some information on other important structures in the TRUE Block Scale volume that were not part of the tracer tests, such Structures #19, #6, #7, and #10.

1.1 Flow Dimension

The classic two-dimensional approach assumes that the conducting feature is a tabular-shaped conductor oriented perpendicular the wellbore axis. The interpretations presented here use a generalized dimension approach (Barker, 1988), which makes no assumptions of the conductor geometry. Thus the interpretations provide information on the geometry of the conducting feature as well as its conducting properties.

Barker (1988) introduced the generalized radial flow approach to the hydrologic literature. Essentially it defined the dimension of a conductor as the power at which the conducting area grows with radial distance from the pumping well, assuming homogeneous hydraulic properties. If the properties are not homogeneous, the dimension reflects the power growth of the product of area and hydraulic conductivity or conductance. The fractional dimension approach is described in detail in Doe and Geier (1990) and is summarized here.

The dimension, n, is related to how surface area, A, grows with distance from a well, r, by a power relationship, $A \propto r^{n+1}$. For classical two-dimensional aquifers the conducing area grows with the first power of radius. Linear flow geometries, such as a vertical hydraulic fracture or a channel have areas that do not grow with distance, or the power exponent is zero. Spherical flow occurs when the area grows at power of radius squared. Fractional dimensions arise when the area grows by a non-integer power. Such as case may arise from a variety of geometries, but a general explanation involves conducting geometries that are not space-filling or involve leakage. Consider, for example, a two-dimensional planar conductor. If the space is uniformly conductive or if a heterogeneous pattern uniformly fills the two-dimensional space, the conductor will have a dimension of 2. If the conductive pattern does not fill the space, the conductor may have a dimension somewhat less than 2 (Doe and Wallmann, 1995). Indeed dimensions of 1.7-1.8 are common for planar features. Leakage over the conductor surface may lead to a dimension somewhat greater than 2. Some dimensional information can be interpreted from the pressure-time curve of the well test, however, re-plotting the data in terms of the pressure derivative is significantly more useful means of determining dimension.

Well test dimensions exist independently of the porous or fracture nature of the flow geometry. The dimension is simply related to how conducting area grows with distance. One can conceive both fracture and continuum geometries that will produce identical well test results, hence a particular dimension, such as dimension 1, is not by itself an indicator of fracture flow.

1.2 Pressure Derivative Analysis

Bourdet (and others, 198:) originally proposed the derivative curve as a means of identifying the time at which the semi-log approximation of the Theis or Exponential Integral curve becomes valid. This semilog relationship underlies most well test analysis. Recognizing that $n=2$ flow has this semi-log relationship, Bourdet reasoned that a log plot of pressure change versus log time should have a zero slope, and this zero slope would be more diagnostic than a semilog straight line. This pressure derivative plot has advantages in dealing with generalized or fractional dimension flow, because a pressure derivative curve will approach a slope of $1-n/2$ for all dimensions including those between 2 and 3.

The dimension of the conductor is readily recognizable from the shape of the well test curve and particularly the shape of the derivative. For constant rate tests, the slope of the build-up or draw down curve in logarithmic plots will be equal to *1-n/2* for dimensions less than 2. Thus a linear flow conductor will have a characteristic ½ slope.

Figure 1 shows the range of derivative curves for dimensions, where the derivative slope varies from +0.5 to –0.5 for flow dimensions varying from 1 to 3. Non-integer dimension systems produce derivative slopes lying between the integer dimension curves. For example, a conductor with a dimension of 1.5 will yield a curve with a slope of ¼.

Boundary effects are also very clear in derivative plots. A positive unit-slope in the derivative curve indicates a no-flow boundary, such as the limit of a compartment. A steeply dropping derivative (steeper than –0.5 slope) indicates intersection with a more permeable feature at some distance from the pumping source.

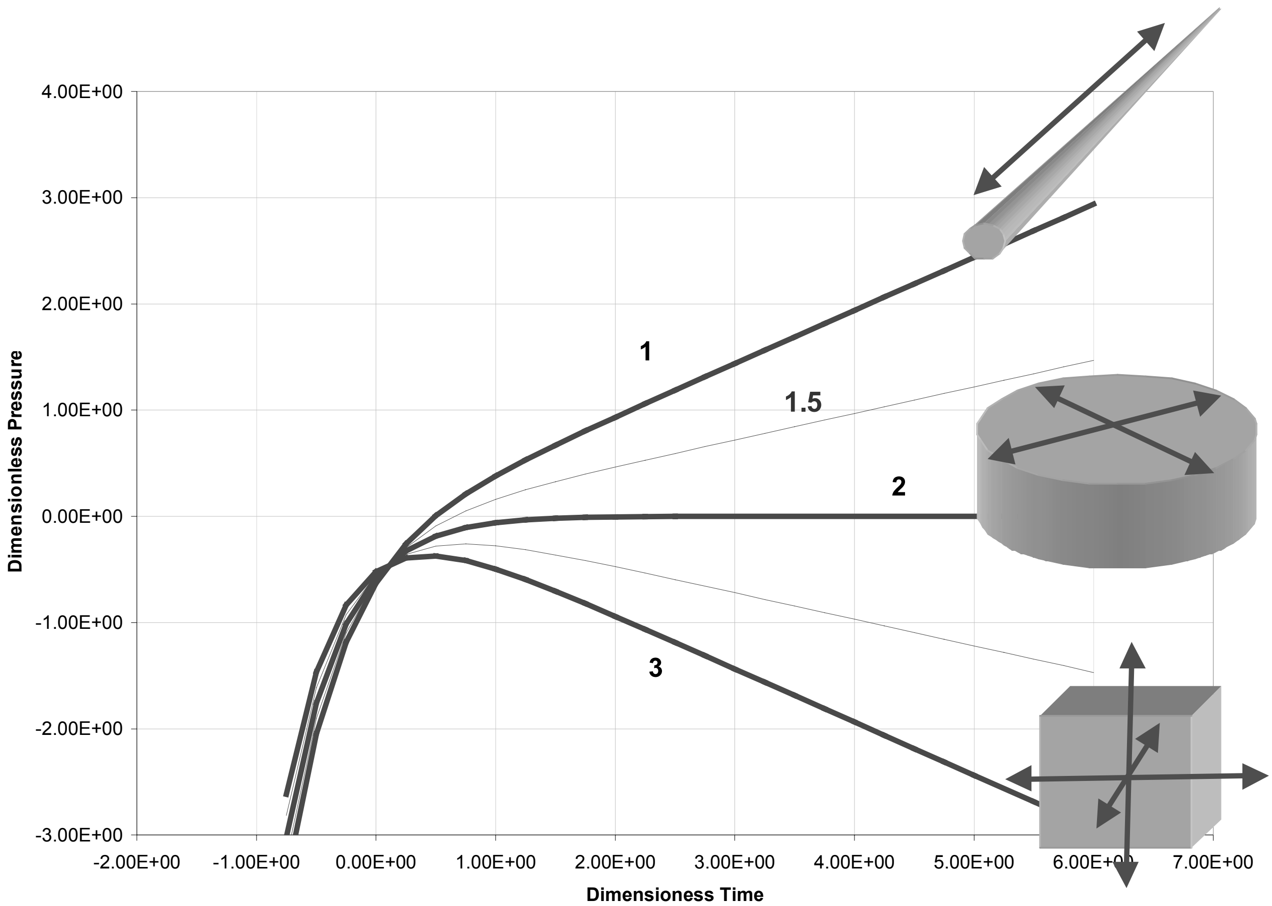

Figure 1. *Illustration of flow geometry and pressure derivative curves. Numbers on curves indicate flow dimension.*

2 Data Sources and Preparation

The analyses were carried in two parts -- pumping zones and observation zones. The pumping zone tests are in two groups:

- Pumping zones in KI0025F02 using short buildup tests, and
- Pumping zones in and near Structure #20 that were run as part of the tracer testing program.

The KI0025F02 short-term build-up tests (Adams, et. al., 1999) provide a derivative plot for each of the major conducting structures in the TRUE Block-Scale volume. These tests were relatively short (about half an hour), and they were conducted with the entire hole open except for the packer-isolated flow interval. By contrast the tracer Pre-tests, which were run to select tracer injection and pumping locations, ran for up to several months, and provide a deeper insight into hydraulic property variations with distance from the pumping section.

In addition to the source hole data, a selection of observation hole results from the Phase A tracer tests were also analyzed. The selection came from the A-5 tests which used KI0025F03:P5 as a source in Structure #20. Observation results characterize connectivity between sources and observation points. Particularly important is the use of observation responses to calculate hydraulic diffusivity, η, which controls the speed of propagation of pressure disturbances in the flow system. Diffusivity, which is the ratio of transmissivity (or hydraulic conductivity) to storativity (or specific storage) is essential to defining the scale of investigation for the well test data.

The pressure data were extracted from the Äspö database, and imported into FlowDim, a well-test analysis code (Golder Associates, 1999). FlowDim provides type-curve matching analyses and also outputs pressure and derivative curves that are adjusted for buildup superposition effects, initial time and pressure uncertainty, and noise in the derivative data. FlowDim analyzes pressure recovery data by calculating type curves based on the superposition of a simplified pressure and flow history. The exported data were taken into a spreadsheet and normalized with respect to flow rate. The resulting pressure derivative data were converted to equivalent two-dimensional transmissivity and plotted with respect to time and distance from the pumping source.

The conversion of the pressure scale takes advantage of the use of the pressure derivative's relationship to transmissivity. Transmissivity is commonly calculated using the semi-log slope of the pressure data versus time. The pressure derivative is identically the semi-log slope, and one can determine transmissivity by

$$T = \frac{\rho g}{4\pi t \, {}^{\mathrm{d}p}\!/_{\mathrm{d}t}}$$

where $t \, {}^{\mathrm{d}p}\!/_{\mathrm{d}t}$ defines the pressure derivative, with pressure and time in compatible units for the transmissivity.

The rescaling of time uses the equation for radius of investigation (or radius of influence). This radius represents the distance being affected by the well test and the distance where the rock's hydraulic properties are affecting the pressure response curve. This equation $r = 2\sqrt{\eta t}$ (Streltsova, 1988) relates the distance to the hydraulic diffusivity, η, and duration of the test. Note that this diffusivity describes pressure propagation rather than transport retention, which is different process altogether, albeit governed by the same equations. The scaling of time into distance requires knowledge of the diffusivity of pressure propagation, which is estimated from observation well responses. Typical diffusivities in major conductors range from about 1 to 20 m^2/s. As diffusivity is the ratio of transmissivity to storativity, high diffusivity values can result from either high conducting properties or low storative properties. Conversely, a highly conductive feature can have a lower diffusivity if it is also associated with a relatively large amount of porosity. Note also that the storage porosity needs only to be connected to the flow path and does not need to be directly in the conductive flow path.

Because of the lack of constant-rate conditions during the pumping tests, we exclusively used pressure recovery data.

3 Results

3.1 Pumping sections used during the Tracer Test Stage

The best data for flow geometry analysis was obtained during the tracer test stage as this phase of fieldwork produced the longest pumping durations and hence provides information over the largest distances of any hydraulic testing in the block. This work did not undertake a review of all tracer-test stage data, because many tests were repeated on the same intervals during the Phase A, Phase B, and Phase C tests. For example, the Phase B and C tests only used the KI0023B:P6 sink, which had been tested previously during the Pre-tests (PT tests) and the Phase A tests. Although hydraulic properties can change with pumping, most of these changes are negligible or occur very close to the well, hence this study focussed only on one longer term test for each pumping interval.

The pumping section analyses look at two basic plots — rate normalized derivative plots and transmissivity-distance plots.

Rate-normalized plots provide derivative data for all the selected source zones in a common plot. Pressure and derivative data are normalized to the rates to allow a direct comparison among tests that were conducted at different rates. Similar pressure responses in the derivative curves, particularly in the later portions of the derivative curve can indicate that different tests are influencing the same conductive structure. Conversely, different or inconsistent behaviors between tests can suggest that the tests are influencing separate conducting structures.

The transmissivity-distance plot converts the derivative to an equivalent two-dimensional transmissivity on one axis and converts the time to distance using the radius of investigation formula discussed in Chapter 2. There are several words of caution with regards to the time-distance plot. Composite systems, where the hydraulic properties change with distance, produced plots with two stabilized derivatives separated by a transition period. For example, consider a composite system with step change in transmissivity at some radius. If both cylindrical shells of the composite are two-dimensional, i.e. cylindrical flow, this system will produce a pressure derivative with two flat portions, earlier for the inner shell and later for the outer shell, each portion having its own constant derivative value reflecting that shell's transmissivity.

A transition period separates these two stabilized-derivative regimes. This transition period can last for a log cycle of time or longer depending on the transmissivity and diffusivity contrast of the two composite regions. The transition period appears to be a change in property over some distance in the transmissivity-distance plot; however, it may in reality reflect a step change in values. Hence, it is best to treat the transition portions of the plot qualitatively and reserve quantitative interpretation for the time-distance periods where the derivative is clearly stabilized to a particular shell's properties.

Figure 2 shows the normalized derivative curves for the source zones. The results come from the following tests:

KI0025F02:P5	Structure #20Pre-Test 3 (Andersson et al, 2001)
KI0023B:P4	Structure #13Pre-Test 1 (Andersson et al, 2001)
KI0025F03:P5	Structure #20Test A-1 and A-5 (Andersson et al, 2000)
KI0025F03:P4	Structure #21Test A-2 (Andersson et al, 2000)
KI0023B:P6	Structure #21Test A-4 (Andersson et al, 2000)

When considering derivative plots, note that the transmissivity varies inversely with the derivative value, hence tests with higher derivative values have lower transmissivities, and changes in the derivative to higher or lower values indicate property changes to lower and higher transmissivities respectively.

A distinctive feature of the Figure 2 plot is the similarity of the derivative curves for the test sections including Structure #20. After an early drop in the derivative (reflecting skin effects), each section including Structure #20 has a derivative that indicates a flow dimension between 1.5 and 2. The plot also shows that the important source zone, KI0023B:P6, that is usually stated as a Structure #21 intersection, clearly behaves as though it is part of Structure #20. After about 0.2 hours (10 minutes), the derivative values steadily fall indicating an increase in conductance. This falling derivative does not reach a stable slope — a negative half slope would indicate spherical flow. Rather, the concave downward form of the derivative suggests a constant pressure boundary or a transition to a higher conductivity region. After about ten hours, this transition region appears to stabilize at a constant value indicating a dimension 2 conductor. However, the derivative in this late-time region is noisy and the tests do not run long enough to indicate unambiguously the dimension of the ultimate system that Structure #20 appears to intersect.

Figure 2 also shows derivative curves for the pumping sections which include Structure #13 (KI0023B:P4) and Structure #21 (KI0025F:P4), respectively. These sections have lower transmissivity than the Structure #20 zones. The two zones have very similar derivatives, both having a flat derivative at a value of about 2×10^{7} Pa-s/m^{3}, which relates to a transmissivity of about 5×10^{-8} m^{2}/s. Both derivatives have the same drop with time indicating transitions to regions that are more conducting. The curves are similar but offset in time suggesting that KI0025F03:P4 is intersecting the two-dimensional flow region and sees the higher conductance region before KI0023B:P4, hence KI0025F03:P4 is closer to the higher conductivity region. In short, these two intervals appear to be seeing the same conductive geometry but from different points in the system.

Curiously, the derivative values in these two intervals do not drop to the same level as those in the sections containing Structure #20. This behavior contradicts the hydrostructural model of the TRUE block scale volume (Doe, 2001) which would have Structure #21 connecting Structure #13 to Structure #20. Hence, the hydrostructural model would predict that the derivatives of Structures #13, #20, and #21 would stabilize at the same value. The derivative analysis rather suggests that the piezometer sections associated with Structure #21 in Figure 2 are seeing the same conductor as the sections associated with Structure #13 in the hydrostructural model.

The source zone tests do not clearly indicate spherical flow, however if one could interpret higher dimension flow from the derivative behaviors after about 10 minutes, albeit with spatially varying properties, as there is not clear stabilization to a particular derivative slope. Nonetheless, a very important point in this analysis is that the tracer injection points, and hence the tracer pathways are all less than 100-m in length, hence *the flow dimension that is relevant to tracer test interpretation is a dimension of two or less.*

Figure 3 is the transmissivity-distance plot for the same data shown in Figure 2. As discussed in Section 2, this plot transforms time to distance using the hydraulic diffusivity. The plot gives distances assuming a constant diffusivity of 5 m^2/s, which is an approximate value, derived from the interference responses from KI0025F03 to KI0023B and KI025F02. The diffusivity values to more distant points, KI0025F and KA2563A are larger, as discussed below; hence the distance values in Figure 3 are likely to be underestimates for these sections.

The uncertainty in distances based on diffusivity is not as severe as one might initially think for two reasons. First, as diffusivity values, as the ratio transmissivity to storage, have smaller ranges in fractured rock than transmissivity. Second, distance scales as the square root of diffusivity; hence distance values have a smaller range of uncertainty than the underlying diffusivity numbers. As an example of the reduced uncertainty range for distance, a factor of nine uncertainty in diffusivity translates into a factor of three uncertainty in the distance.

The transmissivity distance plot shows that the transition period from the local transmissivity of Structure #20 to the feature or system that is acting as a constant pressure boundary occurs at about 100 meters. If we use a higher diffusivity, such as that derived from the more distance interference tests (about 30 m^2/s) the distance to the boundary increase to about 250 meters. One way to assess the appropriate distance is to look for geologic features lying between 100 and 300 meters, and see if there are good candidates for this boundary.

Figure 4 shows a map of the TRUE Block Scale Volume relative to major Äspö structures EW-1 and NE-2. Both of these features are in the boundary distance range suggested by the transmissivity-distance plot.

3.2 Pressure Interference Results

Pressure interference data were analyzed for the A5 tracer test. The focus was primarily on sections including Structure #20, but nearby pathways were also considered. The pressure responses are plotted in Figure 5.

There are a few key features to the interference responses. First, the Structure #20 intervals, including KI0023B:P6 show an obvious similarity of behavior that indicates these are part of a common conductive structure. By comparison, other nearby zones that are plotted clearly have different and delayed responses, and appear to be parts of different, though possibly connected, conductors. *If the fracture network were one single spherical flow system, all interference responses should be similar with distance regardless of structure and should have slopes appropriate to spherical behavior.* The structures are clearly having a dominating effect on the interference responses.

Another key point is the variation of diffusivity within Structure #20. The diffusivity values for the interference responses are given in Table 1.

Table 1. Diffusivity derived from selected interference tests.

Observation Zone	Structure	Distance m	Transmissivity m^2/s	Storativity -	Diffusivity, η, m^2/s
KI0025F:S4	#20	34	1.4E-06	8.6E-08	16.3
KI0025F02:P5	#20	9	8.5E-07	3.7E-07	2.3
KA2563A	#20	27	7.1E-07	1.2E-07	5.9
KI0023B:P6	#21	16	9.5E-07	4.9E-07	1.9
KI0023B:P7	#20,#6	16	1.6E-07	6.1E-08	2.6
KI0025F02:P6	#22	11	8.9E-07	2.0E-06	0.4
KI0025F02:P3	#13 splay?	20	9.5E-06	1.5E-05	0.6
KI0023B:P4	#13	18	9.5E-07	4.0E-06	0.2

Of key note is the relative lower diffusivity values for the closest interference points (KI0025F02 and KI0023B) of 2.3 and 2.6 m^2/s respectively and the higher diffusivity values for KI0025F and KA2563 (16.3 and 5.9 m^2/s respectively). There could be a decrease in transmissivity between the pumping section and the more distant observation points, but one does not see this in the form of the derivative. Rather, the lower diffusivity values could reflect higher storage and higher porosity near the core of the TRUE Block Scale tracer activities and Structure #20 has lower porosity further away. This suggestion could be corroborated by reviewing the geologic descriptions of these intervals and comparing the degree of alteration and damage.

3.3 Flow Dimension Behaviors in Other Structures

Long term transient tests have only been performed for the design and execution of tracer tests. Hence the selection of source zones has emphasized Structure #20 and nearby structures. There are no longer term tests on other structures, such as structures #5, #6, #7, #19, or #10. These data are not critical to the tracer testing, however, they are of interest to the overall hydrostructural model or to any future work in the TRUE Block Scale rock volume that would use these other structures.

The pressure buildup testing in KI0025F02 (Adams, et al, 1999) provides a possibility to take a closer look at these other structures. The tests are not ideal for this purpose as the durations are relatively short and the KI0025F02 was open during the testing except for the pumping interval, hence there is a possibility that the borehole itself was acting as a constant pressure boundary.

Nonetheless, with these caveats in place, Figure 5 shows the normalized derivative plots for the KI0025F02 tests. For this plot the derivative is given as equivalent two-dimensional transmissivity for direct reading of hydraulic properties.

A major feature of the tests is the transition to higher conductance regions in all tests. The transmissivity of the higher conductance region is not same for each test so it not clear if they are all connecting to the same ultimate boundary. The later time behavior may be interpretable as spherical flow for some tests as Structures #6, #7, and #10 clearly have later time behaviors with the distinctive negative half-slope of spherical flow. For Structures #6 and #7, the proximity to the Structure #5 and other related structures might be a hypothesis worth considering for the spherical flow effect. In this case, Structure #5 may be part of a thick high conductivity zone, and spherical flow may be a partial penetration effect of the conductors connecting Structures #6 and #7 to that region.

Conspicuous in the derivative is also the lack of closed boundary behaviors, which would appear as upward trending derivatives with slopes of 1. All of the pressure derivatives ultimately see downward-trending derivatives which indicate constant-pressure boundaries or possibly higher-dimension, spherical flow. There is no evidence in the data there are closed compartments, in that all the derivatives either reach a constant-pressure boundary or some higher dimension flow region. The flow may be compartmentalized in the sense that the major structural groupings (the system of Structure #13 and #20, versus Structures #5 and #10) are mutually isolated but connected to larger features that may or may not be the same larger-scale features outside the TRUE Block-Scale Volume.

Structures #19 and #20 have clear two-dimensional flow regions, as do Structure #23 and possibly #22. Again, the plotting of these derivatives as transmissivity provides a quantification of their flow properties.

Figure 6 shows the pressure derivative results for the short-term build up tests that were performed in KI0025F03 after the installation of the piezometer (Gentzshein and Ludvigsson, 2001). The single-hole test on Structure #20 produces virtually the same results as the A-1 and A-5 tracer tests (Andersson et al, 2000). The tests on Structures #22 and the splay (?) of Structure #13 (which appears in the piezometer section KI0025F03:P3) reflect relatively low transmissivity features near the hole, but intersect a more conductive feature with the transmissivity Structure #20 (and thus possibly Structure #20) in the first minute of the test. Structure #23 produces a response that suggests isolation from Structure #20. Structure #13, which appears in the section KI0025F03:P4 based on drilling interferences is much less transmissive and diffusive in this hole than in KI0023B or KA2563A. One does see a transition from a near hole transmissivity of about 3×10^{-8} to about 1×10^{-7} m^2/s which may reflect intersection the more transmissive parts of Structure #13 in KI0023B or KA2563A.

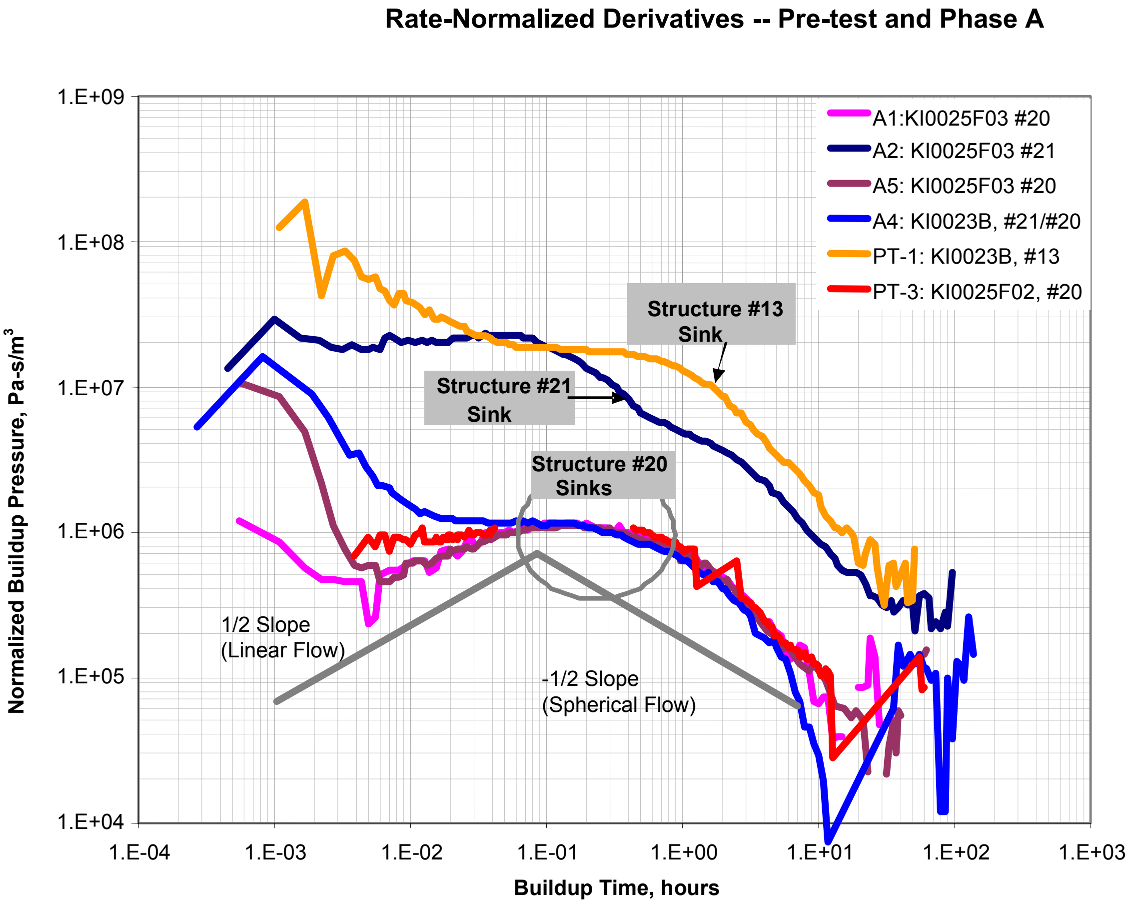

Figure 2. *Rate normalized derivatives for selected pumping sections from the tracer test stage.*

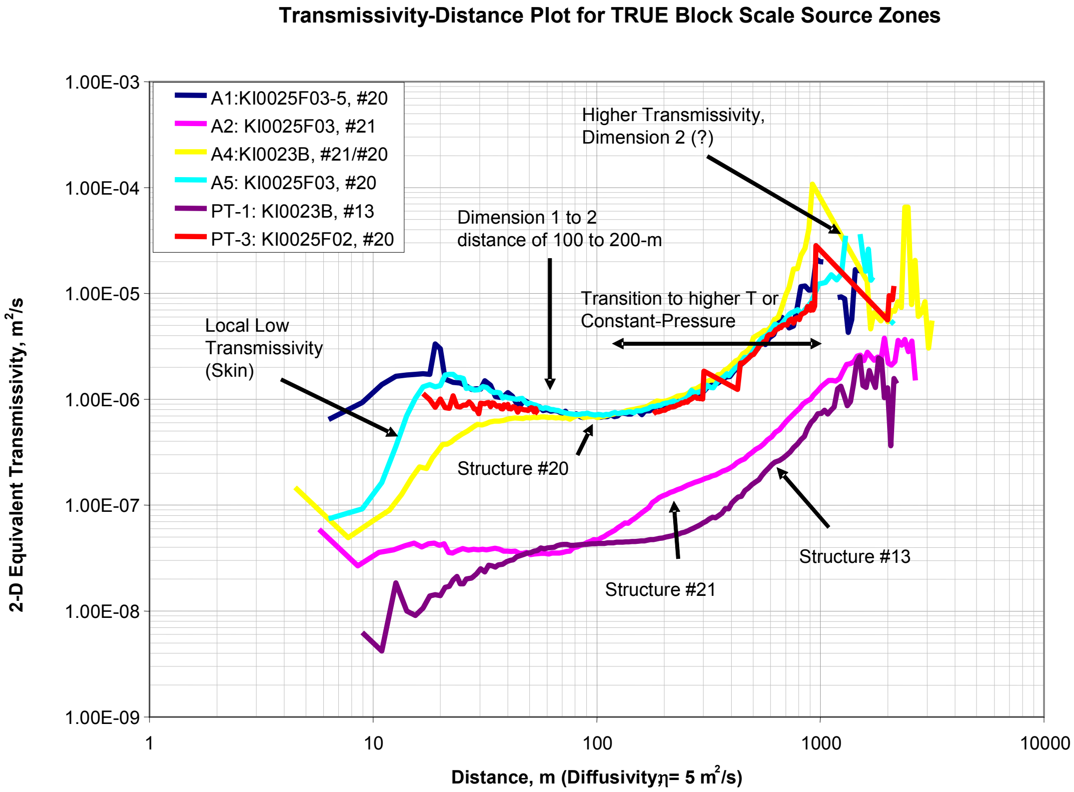

Figure 3. *Transmissivity versus distance for pressure derivatives from selected tracer test stage pumping zones.*

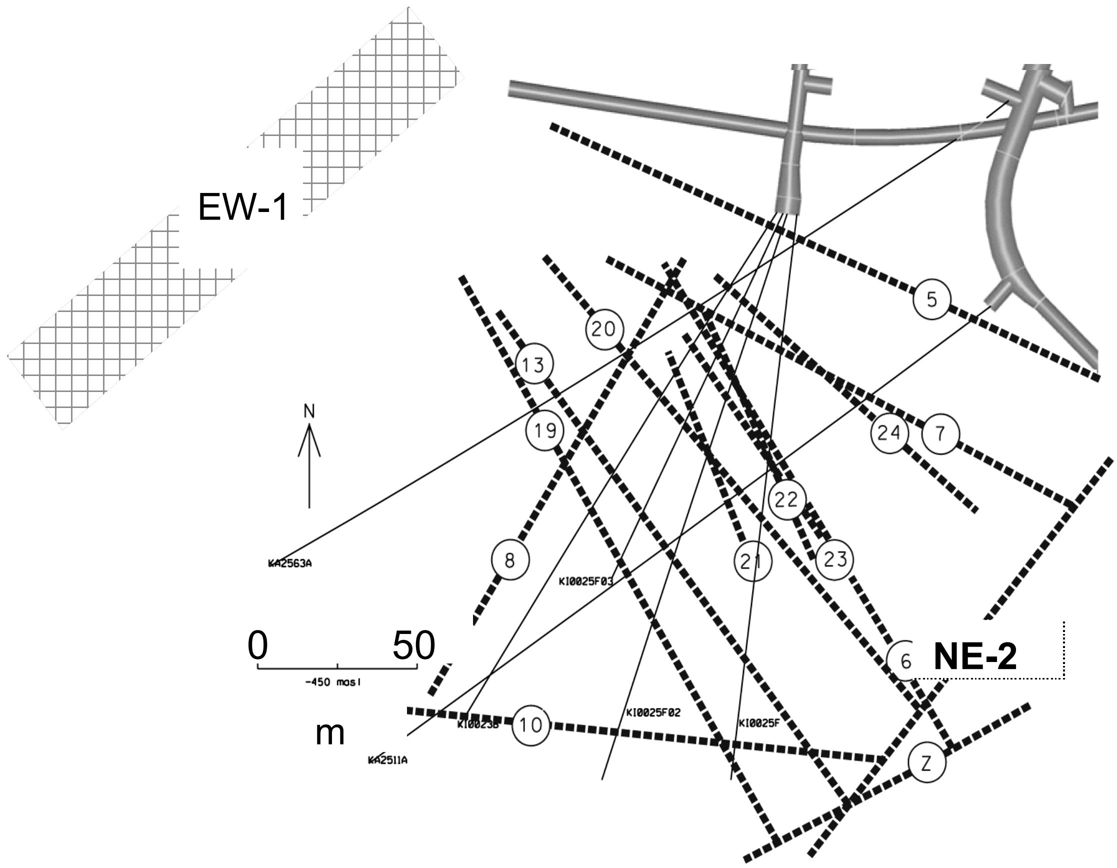

Figure 4. *Locations of EW-1(approximate) and NE-1 relative to TRUE Block Scale Volume to show major structures that are potential candidates for the constant-pressure boundaries seen in transmissivity-distance plots.*

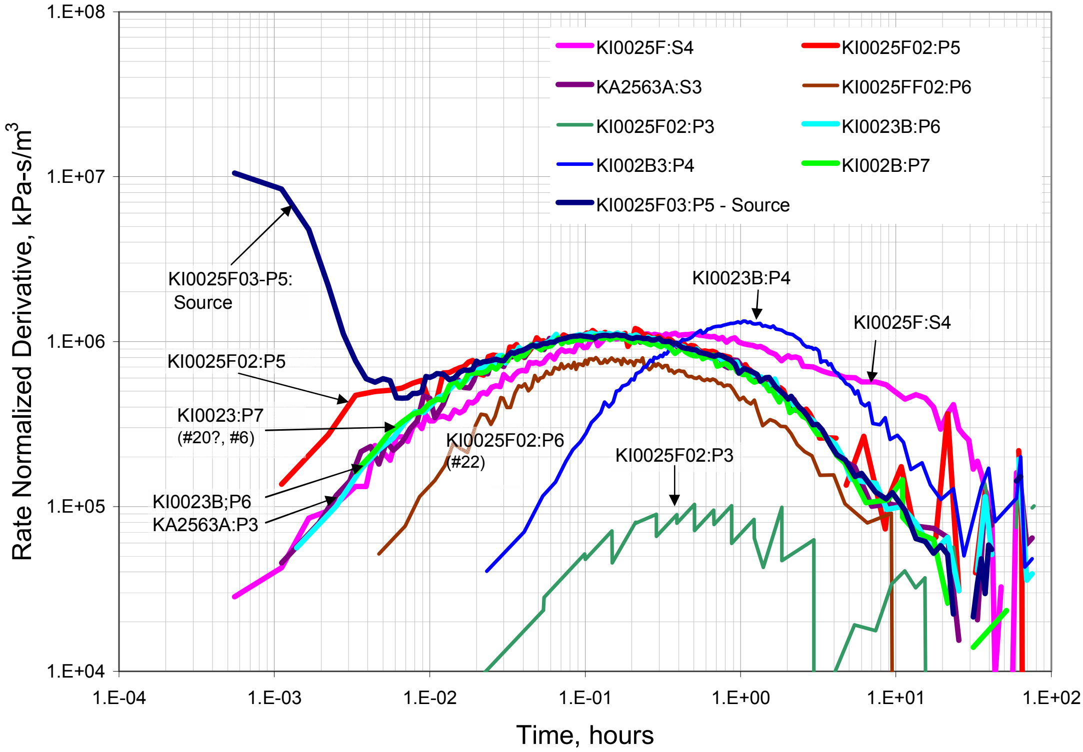

***Figure 5.** Derivative plots of selected pressure interferences from the Phase A tracer tests (Test A5) (data from Andersson et al, 2000a) .*

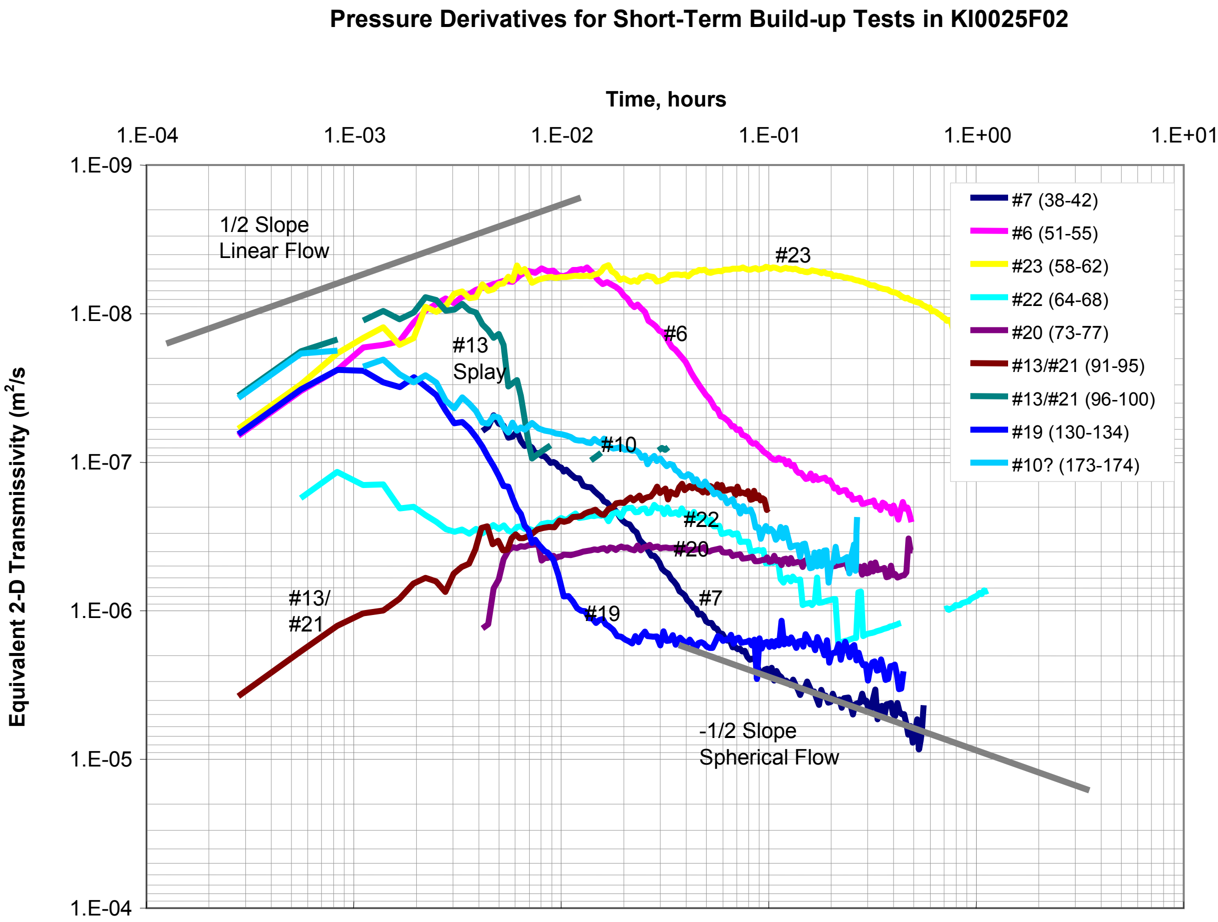

Figure 6. *Pressure derivatives for short build-up tests from KI0025F02 (data from Adams et al., 2001).*

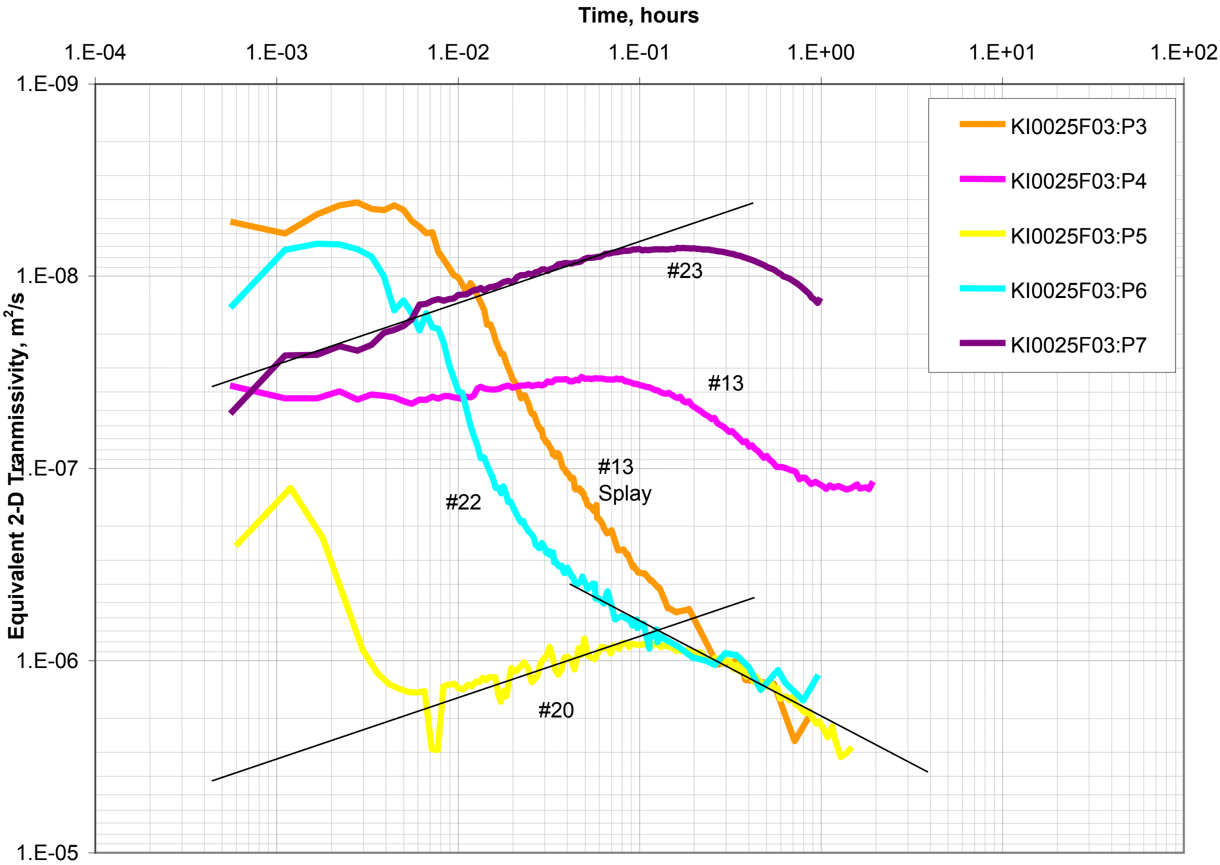

Figure 7. Pressure Derivatives for KI0025F03 Build-up Tests

4 Summary and Conclusions

This report has presented results of geometric analyses of pressure derivative plots for hydraulic tests in the TRUE Block Scale volume. The inspection of these plots allows the following conclusions.

- Nearly all of the intervals ultimately see constant pressure boundaries or higher dimension flow regions indicating that all of the structures have connection to the larger flow systems of the laboratory.
- For Structure #20 the distance to these boundaries is between 100-m and 250-m, the uncertainty being dictated by the range of diffusivity values. This distance is consistent with these boundaries being either EW-1 or NE-2.
- The region of Structure #20 around KI0025F03 and adjacent holes has a lower diffusivity than more distant regions of the structure around KI0025F and KA2563. This lower diffusivity may indicate a higher porosity region within Structure #20 in the core experiment area.
- The region of most interest for performance of tracer tests lies within a portion of Structure #20 that is characterized by Dimension 2 flow or lower.
- Spherical flow may appear in the later portions of tests for Structures #6, #7, and #10.
- Geometric analyses using pressure derivatives are a useful tool for corroborating the hydrostructural models

Based on these analyses, we can make the following recommendations.

- As part of future work on the TRUE Block Scale volume, additional long pumping tests should be performed using other structures as sources, particularly if those structures might be the focus of future tracer testing.
- Modeling work to include matching of transient well-test data would provide an additional check of the numerical models, particularly with respect to the boundary connections, as the boundary connections may be a key part of the observed pressure derivatives.
- Future block-scale modeling should consider using EW-1 or NE-2 as constant pressure boundaries.
- Pressure derivative data analysis with a view to the hydrostructural model should be an on-going activity in the iterative characterization of block-scale volumes.

5 References

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