Comments and Questions from Other Users of the Thomeer Excel Spreadsheet

Concerning "BVinj%",
the Micromeritics raw data provides a "%PV" intruded column which I import via disk to my EXCEL software. I also have to enter into my software a spl BV value (measured during the MICP test) to create a spl "BVinj%" data column, which my software then uses to generate a graph of %BVocc. vs Pc for closure correction. Is this generally what you do, and how does the measured\calculated spl BV value get into the Spreadsheet?

My closure correction question was centered on the "jagged nature" of your %BV vs Pc graph and why a value of something around 0.2 and 0.3 was not entered rather than the 0.60 value? I get the impression your Spreadsheet software strongly controls the closure point selected. I await further lessons on how the closure pressure is selected.

The spreadsheet captures the data and a mathematical form (Thomeer Hyperbolae) which are driven by the operator to achieve a match. THe match may be driven by a math criteria (minimized residuals - discussed later) or just visual overlaying. The Math knows no closure correction, so **the operator drives the match between closure corrected real data and the math.**

The beauty of the spreadsheet is that this can all be done quickly and rapidly over and over again until the operator is satisfied. It solves for nothing unless told to. I will show you this later.

You can simply type in numbers for the **Clos Corr G1, Pd1 Bv1 over and over again** until a good match results. I suggest you do this with the monomodal pore system **(15)** I sent you. The measured porosity and permeability are simply posted and the BV inf and Thomeer perm are computed and presented. You would expect these to be close in some sense in a good fit to good data. However, sometimes they are not, the operator has to decide whether to force them to match, or honor the MICP data, perhaps the perm measurement is off, perhaps the sample porosity is off?? Maybe the bid surface vugs affected the perm measurement and the jacket seal was poor.

Note: In a bimodal sample the Thomeer permeability is only computed from the large PS1 pore system.

The data, the closure corrected data, the Thomeer math BV1, BV2, BV1 + BV2, BVtot, are all plotted on three plot formats to visualize the process.

Remember that the Thomeer perm equation achieved a 1.82 multiplicative uncertainty against the air perm when run over all the SHell Rock Catalog samples. This means that if Thomeer perm and measured perm are within a factor of two - this is GOOD. Maybe as good as it gets.

At this point, take the simple sample - 15 and after having saved the spreadsheet, play with the numbers across the top in yellow **Closure Corr, G1, Pd1, BV1** and get a feel for the plots and the visuals. IF you save your work save it under a different file name so that you can compare to the original I sent you.

Ed

Also, I have developed a separate EXCEL file into which I can import my Micromeritics raw data and calculate a "%BVinj" column for pasting into your Thomeer Spreadsheet. Over the next few days I plan on working with the Spreadsheet and see what I can do with real spl data. You have sent me several files which I have downloaded and have in EXCEL. Which of these files do you suggest I use to import my spl Pc and %BV data columns so I can select\enter closure, change closure, etc.? [Clerke, Edward] use the sheets Thom200_splnum Play with the data I sent you, I will set you up a spreadsheet for 117 - are you sure of this number?

Ed: I have spent several hours working with the Thomeer Spreadsheets (TS) and feel I have a good understanding of what I will be doing with it. I find your TS interesting and impressive. I can import my MICP raw data into some customized software I have, calculate a "%BVocc." column, and import the Pc and %BVocc columns (118 pressure steps) into the TS (see files below). I have studied your two examples (#15 with PS1 and #103 with PS1 & PS2 pore systems), "manipulated" the various PS parameters, and observed changes in the graphs and data columns. I have tried to determine exactly where your "Pd" and "BVinf" values have come from within the spl data, but am unclear and await your assistance. For example, in your spl #103 the closure correction is 0.60 @ a Pc of 80 psia, yet PS1 has a Pd of 47.00 (psia?) Also, how is the BVinf of 5.00 obtained? I also sense that the input parameters are in part selected to cause the "red plot" to overlay the "blue plot".

I have input two of my spls previously run into your Spreadsheet and entered parameters. These files are attached(Spl #8 - [pttom8.xls] and spl # 94 - [pttom94.xls]). I initially wanted to check out my MICP raw data (to 60000 psia) importation into your TS. Works fine. Once into TS, I have worked with the data and the PS1 and PS2 parameters but found things I as yet do not understand. Might you enter the values and return these files to me with any explanations that are helpful as to where the values come from? And do you provide me with "G" values (I recall this is a "Thomeer #?) or some classification scheme?

And a general question. My MICP test to 60000psia injects Hg into ~100% of the PV for most reservoir-quality rocks. During each test I also accurately measure spl BV by calculating through weighing the volume of Hg displaced by the spl at the Hg-filling pressure. I use this measured\calculated value for the actual spl analyzed as the "total spl BV" and the basis for calc. "%BVocc" from the raw data I notice TS discussion on "vertical asymtope lines" for obtaining some BV values. For 30000psia tests I can relate. To 60000, however, I think the calc BV value on the specific spl tested is a real good value for calc. of "%BVocc" from the raw MICP intrusion data. Comments?

The Thomeer Excel Spreadsheet allows the operator to manipulate the MICP data (closure correct it) quickly and efficiently and then to graphically or mathematically match the closure corrected data to one, two or three thomeer hyperbolae. Graphically, the raw BV occ versus PC data is presented, the closure corrected data is presented and the Thomeer hyperbolae are presented as individuals: BV1, BV2, BV3 and as a composite, BV1, BV1+BV2, BV1+BV2+BV3. The operator decides either visually or by math criteria what combination of pore systems and pore system parameters are best ,given a closure correction.

In the spreadsheet proceeding from left to right, is the PC, BVocc data and successive columns of %BVocc, %BVocc clos corr (the new closure corrected data). Note that the %BVocc column is now zero until the selected closure volume is reached. The formula for the Thomeer Hyperbola is used next to take the 3 Thomeer parameters and generate synthetic cap curve data. This is compared to the closure corrected real data, by visual comparison on the charts and by obtaining the residual (a measure of the difference between the real and the theoretical) in an adjacent column. If the residual is low, the match is good, if it is high is is not good.

And so the spreadsheet progresses in the order real data, mathematical prediction, residual, as each successive pore system is added.

The sum of the residuals for the first pore system is found in **C7 and called the average NORM**. if each residual is small then the sum is small. **SOOOO, one wants C7 to be as small as possible, which is the same as saying one wants the graphs to overlay. More about this later.**

Your assignment

using the single pore system example, 15,

assume BV1 is the porosity measured by Helium, a good first guess, **then put G=0.5 and Pd = the spot where the real data graph is all the way to the right - about 280.**

Now adjust these numbers to get a better and better match**. Watch the cells C7 and the Thomeer Perm (G5) versus measured perm and also watch the graphs and drive the Thomeer parameters to a good fit leaving the closure correction at 0.8. See the c7 cell decline as the fit gets better and better. See the Thomeer perm approach the measured perm, see the BV1 not be exactly the measured He porosity.**

Have fun.
Ed

Ed: I have spent several hours working with the Thomeer Spreadsheets (TS) and feel I have a good understanding of what I will be doing with it. I find your TS interesting and impressive. I can import my MICP raw data into some customized software I have, calculate a "%BVocc." column, and import the Pc and %BVocc columns (118 pressure steps) into the TS (see files below). I have studied your two examples (#15 with PS1 and #103 with PS1 & PS2 pore systems), "manipulated" the various PS parameters, and observed changes in the graphs and data columns. I have tried to determine exactly where your "Pd" and "BVinf" values have come from within the spl data, but am unclear and await your assistance. [Clerke, Edward] My email of this morning is starting this information transfer. For example, in your spl #103 the closure correction is 0.60 @ a Pc of 80 psia, yet PS1 has a Pd of 47.00 (psia?) Also, how is the BVinf of 5.00 obtained? [Clerke, Edward] Secondary pore systems later. I also sense that the input parameters are inpart selected to cause the "red plot" to overlay the "blue plot". [Clerke, Edward] Yes

I have input two of my spls previously run into your Spreadsheet and entered parameters. These files are attached(Spl #8 - [pttom8.xls] and spl # 94 - [pttom94.xls]). I initially wanted to check out my MICP raw data (to 60000 psia) importation into your TS. Works fine. Once into TS, I have worked with

the data and the PS1 and PS2 parameters but found things I as yet do not understand. Might you enter the values and return these files to me with any explanations that are helpful as to where the values come from? And do you provide me with "G" values (I recall this is a "Thomeer #?) or some classification scheme? [Clerke, Edward] You have done well, your intuition is correct, more information will be coming.

And a general question. My MICP test to 60000psia injects Hg into ~100% of the PV for most reservoir-quality rocks. During each test I also accurately measure spl BV by calculating through weighing the volume of Hg displaced by the spl at the Hg-filling pressure[Clerke, Edward] What is this pressure exactly? I mean what is the criteria?
. I use this measured\calculated value for the actual spl analyzed as the "total spl BV" and the basis for calc. "%BVocc" from the raw data I notice TS discussion on "vertical asymtope lines" for obtaining some BV values. [Clerke, Edward] These are BVinf parameters, the BV1, BV2 ... and are the mathematical asymptotes of the hyperbola, i.e., the infinite pressure mercury porosity and are not the mercury porosoity at 30,000 or 60,000 but should be close.
For 30000psia tests I can relate. To 60000, however, I think the calc BV value on the specific spl tested is a real good value for calc. of "%BVocc" from the raw MICP intrusion data. Comments? [Clerke, Edward] Yes we need a good bulk volume of the sample but this is not the same as the %BV stuff.

Terminology:

Bulk Volume = bulk volume of sample
%BVocc, % bulk volume occupied = volume of mercury intruded divided by bulk volume sample at each pressure
BV1 = the BV infinity parameter used in the first Thomeer hyperbola
Ed

Excel has TOOL called the SOLVER. If you do not have this active you need to activate it. It should be a selection on the Tools drop down menu. See Excell Help to activate it.

Open up the Thomeer spreadsheet "thomeer_hagerty_15_v5 and start with typical defaults:
BV1 = por= 10.2
Choose Pd by inspecting where the closure corrected curve is all the way to the right roughly 250
Set G = 0.5 this is always where I start this.

Now Tools Solver

Set Target Cell to C7.
check Min box
by changing cells e4:g4 "You are going to let it find the G Pd Bv values to minimize C7"
subject to the constraints - use the Add box
  e4>=0
  f4>=0
  g4>=0
options:
  check Assume nonnegative
  check Use automatic scaling
OK

then Solve
watch the bottom left of the spreadsheet
the Solver automatically finds new values of G1, PD1, BV1 that makes C7 a small number
examine the graphs before you choose to
Keep SOlver SOlution
Restore Original vALUES

SOlver should have returned to you

G = 0.34
PD = 271
BV = 11.5

and C7 = 0.20

YOu can try this with asking it to also find the closure correction in the By Changing Cells Selection, though this does not alway work well. You can start with almost any guess for the Thomeer parameters and let Solver do the work for you but in practice, you need to start close to a good match and then let it fine tune it. This is how I redid your data.

More later about dual pore systems. and fine tuning the C7.

Your assignment - play with Solver on single pore systems.

Ed

Ed;

Received your E-Mails this Monday and have spent time today going through several.
Two points this Monday evening:

1. Thanks for the revised "master Thomeer Spreadsheet" to accommodate my pressure table. However, I need 125 rows rather than 124 to receive the 118 pressure steps reflecting the 117 pressure steps. At your convenience.

Ed: All is well!

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A general question at this time. Is the "best" MICP data fit on the spreadsheet dictated by (1) the lowest "AVER NORM" value or (2) the "best" overlay of the blue line by the red line? If I find that changing a particular "G", Pd, and\or BV value after the solver program runs gives a better overlay but increases the aver norm value, which rules?

COngrats! First tell me how you like running this thing? I think it is a lot of fun.

The average Norm if you look in the formula is the sum of the residuals (the difference between the math and the data) from O8 to O125. **SO the average norm says every data point is important in equal proportion?!** We know this is not true, we may take 118 data points but only

30 may be in the curved portion of the cap curve, the rest may be asymptotic values There may also be a glitch between the two transducers, and so on.

The Average Norm computation can be edited!

You can clear cells in the O column that you don't want to contribute.

You can change C7 to be the sum from O8 to say, O 50 to emphasize the low pressure part of the curve first. As is necessary in a dual porosity cap curve.

You can drive it graphically, all the information is presented, judgement is not. In the end, you must decide, and you looked at the sample.

My practice:

I run the solver and then manually tweak the numbers by using a ranged C7 or driving it visually.

When I finish with a lot of samples - 25, I run back through all of them again to investigate intersample consistency.

Once Average Norm gets very low, .02 to .002 these are all acceptable mathematical solutions, the Human must select the best parameters even if the Norm increases somewhat. Look in O column to see where these contibutions to C7 Average Norm are actually coming from.

Ed: I owe you a discussion on my MICP measured\calculated spl BV @ 60000psia.

The MICP test starts with the spl sealed in a penetrometer (spl holder) and a vacuum less than 50 microns drawn. Next Hg is "pushed" into and completely fills the penetrometer at the "Hg-filling pressure" of, say, 1.62psia. At this pressure Hg will intrude pore throats with diameters > ~130 microns. By weighing the Hg-filled pen and knowing spl wts, empty pen wts, pen vol, etc., I can calculate the "BV" of Hg displaced by the spl (ie, calculate spl BV). Note that at this Hg fill pres all spl surface vuggy pores with dias. > 130 microns are intruded with Hg and not included in the MICP data.

For carbonates with surface vugs, I have the option of lowering the Hg-fill pressure to ~0.70psia, which would intrude only those surface pore throats with dias. > ~300 microns. For these rock types we also see quite high Hg intrusion values over the first several pres. steps as the "smaller" surface vugs are intruded. In other words, Hg-intrusion data can be obtained on the surface vugs with throats < ~300 microns. but this "vugular porosity" intrusion is eliminated by selection of the closure pressure related the the beginning of Hg intrusion into the "matrix" pore system? Perhaps for some of your vugular rock types we can included this "initial" Hg-intrusion data in some way to "capture" a portion of the vugular porosity in the MICP data? Always available to discuss.

I also correct (reduce) the calculated "filling-pres spl BV" for the volume represented by the amount of closure. Hence the measured spl BV used for generation of my "%BVocc" at each pressure step table, which is imported into your Thomeer Spreadsheet, will be the measured spl BV at the pressure at which Hg begins to intrude the "PS1" pore system.

Ok thanks, I am with you on this.

In deed, the method is self consistent, however, an additional important question is the tie to the BV inf, %BV at 60,000 and the He porosity? **That is, the BV measurement should be consistent with the degree of surface conformance that occurs in the He porosimeter sample holder.** If a solid cylindrical sleeve is used in the He por, then maybe the BV needs to be just a measurement of the plug length and diameter. Remember, eventually, I need to tie BV@60,000 to Phi from logs which sees porosity at all size scales.

Then this being done(plug micrometering), the %BV occ at 1.62 psia is a measure of big vug porosity which will be incompletely characterized and if this is a large part of the total POR, the recommendation is to then perform whole core MICP analysis??

With the protocol we have in place,

- the Closure Correction is that minimum volume correction which allows for the corrected data to be fit by a Thomeer hyperbola, and the
- BV is the measure of the Bulk Volume measured with a degree of surface conformance similar to that of the He porosimeter,
- Then the closure Correction now has geological significance and I have found it too can be related to rock types - pore systems - hence the need for your visual descriptions.

Ed

1. I need "quality" right cylinder plugs cut for which we can obtain a good (accurate), calipered spl BV that will include any\all surface vugular pores. This is important

2. We can measure an unsleeved Boyle's Law He Grain Volume (GV) which, with the calipered BV, gives us a spl PV (BV-GV) including all surface pores.

3. My MICP test will use a "Hg-fill" pressure that will intrude Hg into any surface pores with pore throat dias. down to XXX microns (ie, 1.62psia = 130microns). The spl BV @ fill pres. is measured. The remaining spl surface vuggy PV will be intruded (measured) by the MICP test intrusion data up to the closure pressure when we begin to saturate the matrix pore system with Hg. At the closure pres. we also calculate the **spl BV (excludes surface vug pores).** You have some option on the specific Hg-fill pres best used, but I want to use a standardized pressure table for all spls if at all possible. [Clerke, Edward] Ok let's keep this distinction clear and annotated that the Hg 1.62 BV excludes surface vugs BV130-

4. Using data from 2 and 3 above we can calculate total spl surface vug PV, including separate PV values reflecting (a)% surface vug PV filled at Hg-fill pres, and (b) % surface vug PV occupied from "fill pres" up to closure pres. Perhaps you will want a certain Hg-fill pres. to affect the 4A vs. 4b values.

5. I propose to provide a "Lucia-Type" description of surface vugular pores as observed at ~10X under a binocular microscope, including any specific properties you want for your utilization of these data. [Clerke, Edward] If you want to go this route I request Archie rock type and Lucia

6. The spls with no vugular porosity will allow a check\calibration of these various "BV" calculations.

I've imported the MICP data into the ThomFit spreadsheets and generated my "best fits", including editing of the "O" column. Data OK? A question; plug #2 shows a "BV1+BV2" value of 33.1%. I understand the "thomeer asymtope" basis for this summation value, but plug porosity via both He and MICP is only ~28.5?!

Further,
we do not now cut 7/8" plugs. SO figure on your having to cut them from 1.5" plugs that we send you. Is this okay?
Ed

I have reviewed your fits and while agreeing that the pore size distribution looked good, this plot is not very definitive in getting the BV's right. The BV occ vs pressure plot did not look that good. I observed the second pore system kicked in at about 3000 psi or so which corresponds to cells about 90 so I set aver norm in C7 to be O8 to O90 and aver norm in P6 to be O90 to O125.

I used the solver on the first pore system only with the new C7 as target. I then used the solver again on the second pore system with P7 as the target and only allowing it to guess the second pore system parameters.

BV Results

	POR	BV tot
SPL 1	26	31
spl 2	29	32

SO now with this result, there is still a discrepancy. The spl 2 is why I sent you the SHell Rock Catalog comparison of Thomeer BV to Por and that email exchange of some time ago.

SPl 1 at 60,000 is still taking mercury, so this discrepancy must be discounted as we have not turned to corner on the micropore system.

Let me say that you have made good progress and that all of the charts are useful in getting a good final fit.

Groups of 20 to 25 samples or once a month deliveries by email with a CD every quarter will work. If you want to collect spreadsheets in a work sheet that is fine. Be sure to back them up as I have had some problems with Excel file corruption.

Finally, you are free to use the Thomeer spreadsheet for other clients with the acknowledgement somewhere of Ed Clerke.

Ed:

Thank you for your input on my 2 carbonate "test" spls. I understand what you did, and it gives me a better understanding of how you obtain the "best" PS2 parameters. In the next week I may do 2 more carbonates and have you check. Alsooo, I have set up my internal MICP software to import\export raw data and conduct "ThomFit" work on up to 24 spls within one "saved as" file.

As concerns my MICP size requirement for plugs, I need to have "quality" plugs of the required diameter\lenght cut from your 1.5inch plugs so we can measure (caliper) an accurate spl BV value which includes any\all surface vugular porosity

My MICP work on your spls will give us four(4) "spl BV" values; (1) calipered spl BV, (2) spl BV at Hg-filling pres of ~1.6psia, (3) spl BV at Hg-closure pressure, and (4) spl BV summations from "Thomeer". I plan, unless instructed otherwise, to give you in EXCEL spreadsheet these 4 BV values along with spl PPGD values.

Ed,

Boy, I would like to see your capillary pressure data. Can you attach it to an email?

I have been using your program to describe the Tertiary grainstones I got from Dave Budd, Univ of Colorado. Dave point counted interparticle porosity, which comprises about 75% of the porosity. The samples with vuggy porosity types intrafossil, moldic porosity, and intragrain microporosity require 3 Thomeer curves to characterize whereas the samples with mainly intragrain microporosity as vuggy porosity require two Thomeer curves.

More later.

Jerry Lucia

I understand and agree with your comment on "packing porosity" into the first pore system. And I would like to get your "revised" THOMFIT parameters at the earliest possible. That way I can understand your treatment of these MICP data in your software and have any questions in hand when we meet at AAPG.

4. As concerns more data density in the lower pressure range, I can create whatever pressure table you think best suits your rock types. The table used is on log-based pressure steps formulated by EPR several years ago, and it is the table I have used for years. Certainly we can discuss the best table for your next group of samples, perhaps after PPGD data has been generated and we have a good feel for anticipated initial pore entry pressures.

You need to set the spreadsheet up for you number of points and hold to it - 100-200 is advised, spread across the pressure range.

3. The small pore throat diagram is not working because of point 2

4. It is not advised that one gets to the desired number of points by just throwing points away - this creates artificial spikes in the numerical derivative(pore throat diagram)

For many of the 26 spls you pick a higher closure pressure pressure. I have been basically looking at the "raw" incremental Hg intrusion values and selecting the pressure at which Hg appears to begin to intrude the pore system, only going to a higher value when really trying to obtain a lower "ave norm" value. I sense your selection may be based on Excel Solver. Your guidelines?

2. Help me understand the "0.00" values in BV2 BV3. Now I understand your comment of loading the porosity into BV1. As the Solver doesn't automatically assign a 0.00 value, how do you get such values in along with their associated G and Pd values (before or after Solver? Obviously I haven't tried this yet. And help me understand, when I use this approach, what a pore system (eg, PS2) with "0" PV is?
[EAC]
Once you have turned on the three pore systems in order to turn them back off - set the BV to .0001 The other numbers are now meaningless with the PS.

Run Solver using only one pore system first - then do your tweaks. You can run solver on the first pore system only on G, PD with the BV 1 set to the plug porosity or slightly higher. Then you can run the solver with the PS params fixed and let it pick a Clos COrr - and see where it lands? Lots of iterations on the game - in the final analysis - it is you who must drive the solution with solver as a tool. When convinced of the need for a second PS, pick the pressure at which the second pore system turns on - deviates from the first PS curve. Set your target functions C7 to only include the cells up to this pressure (O8, O80) and run it all again for the first pore system. Set the other target for the high pressure range P6 (O80-O200). WHen you definitely need a second PS2, Run the solver over the PS2 params using the P7 cell as the target.

[EAC] Conclusion, **there is many ways to get a fit to the data, some of which make petrophysical sense and some of which do not.** This is driven by the quality of the data, the spacing and the closure correction. The interpreter must come up with a fit that makes petrophysical sense. THe mercury porosity and He por are in some kind of agreement and the Thomeer perm is with in a factor of two of the measured perm unless there is reason to suspect the measured perm - cracks, large surface vugs.

[EAC] In general keep the PS count to a minimum try to do as much as possible with the least number of pore systems. Use a third pore system sparingly. Use a second pore system only if it contains more than one PU. WOrk the closure correction hard and

ALWAYS compare your results to other samples you have analyzed of a similar nature.

please rerun the Thomeer fits only Solving for the parameters of the first pore system, as a general protocol. Only if the data forces you to a second pore system - turn it on as a second solve step allowing it to add its parameters while keeping the first pore system fixed.

I say this as advice for using the spreadsheet for your own educatiion.
The other thing is the way the spreadsheet works, once you turn on a second or third pore system - you can not turn it off by clearing those cells, you have to turn the volume down to 0.001.

When running the solver

Assume a single pore system with BV1 close to POR seed the G1 as 0.5 (this is always a good default) and set Pd1 to just above your closure correction and then SOLVE with a target cell C6

If you really need a second pore system, find the pressure at which the departure from step 1 is significant and put this as PD2, set target cell P6 as the error sum over the high pressure range PD2 and above, set G2 to 0.5 and put a couple pu in Pd2, then SOLVE on P6 with guesses on G2, Pd2, BV 2 alone.

The idea of the spreadsheet is that

We don't have very good rules for picking the closure correction
So the spreadsheet allows you to pick many of them and see the impact.

One guide is the Thomeer perm to measured perm relation - which should be within a factor of 2, but it is only aguide as the measured perm may be wrong!

Generally, we pick a closure correction such that the Thomeer fit is good for all of the data and the BV and Thomeer perm are reasonable with respect to measured values.

Once I get a good Thomeer fit, I often check the sensitivity of the solution to the Closure Correction by running the Solver with the same target cell, but guessing on the closure correction volume! A good fit should give a stable closure correction and the Solver doesn't make much changes in Closure volume.