**Transcript of MCS v.2019 Interpreting a MCS Output File YouTube Video**

**0:00**

In a previous tutorial, we ran an Assimilation & Fractional Crystallization model through the Magma Chamber Simulator. Now let’s go through the output file from that run. To access the output file, we need to go into the MCS folder structure, in our Documents folder we want to open up MCS, and then go to the Input and Output folder. And here we see our Output file, AFC\_Tutorial.xlsx.

**0:32**

Once we open this file (let me give it just a second to think), the first tab that comes up is the Input Tab. And you’ll notice is that it looks quite a bit like the actual MES Input file we created earlier, and it kind of is! Here in the input tab you’ll be able to see not only the exact parameters that you ran the model at (which is basically everything in the MES file), but here at the top we have some extra valuable information. Let’s say you need to repeat a MCS run because you need to adjust one variable, but you ran that model a few months ago and you don’t remember much about it. Here at the top of the Input Tab, you’ll see that both the version of the Magma Chamber Simulator and the version of rhyolite-MELTS that were used to generate the model are recorded. So now, there’s absolutely no question about what the exact nature of your run was, because that information is recorded at the top of the input tab.

**1:34**

Next we have our RunSummary Tab. This is the main place where the results of your phase equilibria modeling are stored. And I’ll go through this column by column here, and we’ll talk a little bit about how to interpret the MCS output data. (So I just need to zoom in, so everybody can actually see things… there we go!)

**1:59**

So the first column we have here is Column B, and the “Melts Run Mode”. And this column tells you what equilibration step the Magma Chamber Simulator is calculating. After that, Column C here records which magma chamber process is occurring – either fractional crystallization (FC), assimilation and concurrent fractional crystallization (AFC), or recharge and mixing (RFC). And if you look closely here, you’ll see that for about the first about 150 degrees of crystallization, we have no assimilation occurring – only fractional crystallization. Columns D, E, and F record the temperature of the Magma, Wallrock, and Recharge subsystems respectively. You’ll notice that as the temperature of the Magma Subsystem decreases, the Wallrock temperature increases - and this demonstrates that the Magma Chamber Simulator really is both energy and mass-constrained, and that the given off by the Magma Subsystem as it cools is really being transferred into the Wallrock system, and heating it up! This is really the hallmark of the MCS and it’s one of the reasons it’s an unparalleled modeling tool.

**3:23**

The total mass of the Magma Subsystem is given in Column G, and the total mass of liquid in the Magma Subsystem is given in column H. The next few columns have to deal with the proportions of different phases in the Magma Subsystem. So Columns I gives the “Total Incremental Mass of Crystals Removed as Cumulates”, or the total mass – in grams – of all phases crystallized (and then fractionated) in the Magma Subsystem *at that particular individual temperature step*. Because that’s a pain in the rear end to add up by hand, the cumulative sum of the same is automatically calculated and recorded in the adjacent Column J, here – that way, you don’t have to do all the work! Columns K and L are similar, but they have to do with any exsolved fluid phase in the Magma Subsystem – so just like before, Column K gives the incremental mass of the exsolved fluid phase at any given temperature step, and Column L here keeps a running tally by recording the cumulative mass of the exsolved fluid phase. The last column that’s yellow – Column M – records the mass fraction of water in the exsolved fluid phase. So this really only applies if you are modeling a composition that contains both H2O and CO2 – because if not, then this number is just gonna be 1 if there’s an exsolved fluid phase, and you don’t really need to worry about it.

**4:48**

The next five columns, Columns N through R, record information on the state of the Recharge subsystem: the total mass of Recharge added to the Magma Subsystem, and the mass of liquid, crystals, and exsolved fluid phases present in the Recharge at its specified temperature, and again, the mass fraction of water in any exsolved fluid phase. Because there was no recharge event triggered during this particular run, these columns are blank. In another tutorial, we’re going to cover the multiple types of recharge triggers that you can employ in the Magma Chamber Simulator, and in that tutorial I’ll discuss how to look at Output Files for recharge events.

**5:30**

Columns S through Y give us information on the state of the Wallrock Subsystem. So because we are considering the Wallrock information, and we are needing its fmZero conditions, we did use that WR Find Solidus step during the run to figure out itws liquidus, solidus, and what the fmZero conditions were for this particular WR composition. We can go back to the Input Tab to check what our Input conditions were, and it looks like we had our fmZero set at 0.05, or, you know, 5% of the wallrock. So the conditions of the WR at fmZero when it’s 5% liquid (in this case it says it’s 4, but we’ll talk about that in a second) are given in Row 4 of the Run Summary Tab, and we can see that our fmZero occurs when the WR temperature is at 750 degrees. So at this temperature, at 750 degrees, there’s 4.0675 g of liq accumulated in the WR Subsystem. And again, I know what you’re thinking – hold up, this isn’t the number 5, it’s the number 4.0675. Well, how close the calculated fmZero is to the fmZero you have set in the MES Input File depends on two different things: the deltaT you are using during the WR Find Solidus Function, *and* where the true fmZero value falls in relation to the deltaT you’ve set. So, if the fmZero value of 0.05 occurs when the WR temperature is 684.2 degrees, but you’ve set a deltaT of 20 degrees, the chances of a calculated deltaT decrement lying at 684.2 degrees is slim to none. In this case, the MCS will take the mass at the deltaT *below* 684.2 degrees (so, say in this example, it’s at 670.5 degrees), which may be somewhere lower than the 5 g you initially set. My advice would be to play around with your fmZero and deltaT for the WR Find Solidus Function a bit, and get as close as you possibly can to reconciling this. And, if you’re not doing any assimilation, you can use the Wallrock Hack function to avoid this altogether, and there won’t be any information in Row 4.

**7:45**

I’m sure your eye has already caught the color-coding schematic we use in our MCS Output files. I find that it makes things a lot easier to interpret, and also to organize. So this next group of columns is given in purple – in fact, all of the information recorded for the liquid and mineral phases in our Magma Subsystem can be found in purple columns. So here first in Column Z (let me scooch over a bit, so we can see all the purple columns at once) … here in Column Z we have the liquidus phase for this run, which is clinopyroxene. Now, these phases are ordered as they appear in the sequence of crystallization. Like the masses of crystals before, each mineral phase will have data recorded in two columns: the first recording the incremental mass of that mineral phase crystallized at that particular temperature step is given in the first column, and then the second column has it calculating the cumulative mass of the mineral phase *up until and including* that particular temperature step. So it’s the *cumulative sum* of the cumulates.

**8:52**

The next group of columns is in white, and records the mineralogy and masses of each phase present in the Wallrock Subsystem at each temperature step (here we go… there it is…). Now, even though we are doing an AFC run, unless the MCS is actually doing a calculation involving the Wallrock Subsystem at that temperature step, this will be blank. And you can see that there are some values down below in blue – these are for the AFC calculations, and we’re going to come around to the AFC calculations later on in the tutorial.

**9:33**

And the next group of columns – again, it’s purple here (scroll back up), and this records the composition of the residual liquid in the Magma Subsystem. Again, this is the liquid composition only – mineral compositions are going to be given in a different tab – that’s going to come later on in the tutorial. So, Step 1 – the phase equilibria portion of the Magma Chamber Simulator – runs off of the MELTS engines, so it will only calculate major oxide compositions. The next two groups of columns are white and grey, and record the liquid compositions of the Recharge and Wallrock Subsystems, respectively. But, right here, these cells are blank, because the Magma Chamber Simulator isn’t calculating anything for either of these subsystems here.

**10:31**

Now we can go on to the assimilation! Let’s scroll down to where the action is happening; to where the cells are highlighted in cyan. The first thing I’d like to point out is in that Column B, the text has now changed from “MagmaEquilibrate” to one of three different Wallrock calculation functions. So the first cyan row is by itself, and it’s a Wallrock Equilibrate step – these are triggered once the set fmZero value of liquid is accumulated in the Wallrock Subsystem. The row is blank right now, but if we scroll over to the right, here in the white columns containing the Wallrock mineralogy and phase masses, we see data! Now that some liquid has accumulated in the Wallrock, the Magma Chamber Simulator is going to calculate its mineralogy and it’s going to record that in these columns - so we can see that we have a stereotypical quartz-2feldspar granitoid composition on our hands here. We can also scroll over to the right even further… over here in the gray, and see what the composition of the liquid is that’s accumulated in the Wallrock Subsystem.

**11:57**

And if we scroll downwards through the AFC data, you’ll notice that each time the Magma Subsystem assimilates some partial melt from the Wallrock Subsystem, the Magma Chamber Simulator records three different entries of data – essentially, it performs three different calculations in order to do this, and each is recorded in a cyan-colored line. Let’s take a closer look at these AFC steps – we can pick any one, so let’s go ahead and… row 54. So if I scroll down to row 54 (I’ll zoom in a little bit) ... you can see in row 53 that this is a fractional crystallization step, and this row isn’t highlighted. So at this particular step, the temperature of the Magma Subsystem is 990 degrees (plus or minus a few), and the temperature of the Wallrock is going to be 773.9816 degrees (uh, obviously there’s no way that thermometry can be that specific, but these are just calculations).

**13:13**

So information is going to be recorded for the Magma subsystem (as we’ve already seen), and in response to the Magma fractionating some phases and giving off some heat, in the next line – our first cyan row – we’ll have the new equilibrated state of the Wallrock subsystem calculated. So one way that we can triple-check that that is the step occurring is to scroll all the way… here, and we check and make sure that it says “Wallrock Equilibrate”. So the second cyan line contains much of the same information, especially the same compositional information actually, as the “Wallrock Equilibrate” step, but it also gives us the mass proportions of melt, crystals, and exsolved fluids at the… er… in the Wallrock at that particular temperature step – and that’s something we can see in the previous calculation step.

**14:18**

Let’s zoom out a little bit… and if we can take a look at a couple of rows here, you should be able to notice some patterns in the data. So as assimilation proceeds, the mass of the Wallrock Subsystem (given here in column S) decreases – and this is something you’d definitely expect to see. Column T gives us the mass of residual liquid accumulated in the Wallrock at that temperature step. So remember fmZero? This is it. At a given Wallrock Equilibration step, whatever mass of residual liquid over the calculated fmZero that is produced gets recorded over here in column W, and that same liquid (that exact mass and composition) is then added over to the Magma Subsystem. The last cyan row that we have is “MagmaIsoTFractionateB” – it’s a mouthful. This is the step where the MCS calculates the new, equilibrated state of the Magma Subsystem, after the partial melt from the Wallrock Subsystem has been added to it. And if we look at the data, we can see that this is actually happening. So the mass of the Magma Subsystem – it increases with every assimilation step. The masses of the minerals present in the magma have changed - of course, depending upon your assimilant composition, you can have new phases show up as well – and, we can go over here, we can see that the composition of the residual liquid in the magma has also changed. Note that in this step, we are *only* finding the new, equilibrated state of the Magma Subsystem – so no fractionation of phases has occurred. Fractionation will occur after this new, equilibrated magma has cooled whatever temperature decrement you’ve set, and then the fractional crystallization calculation can proceed as normal.And that’s really all of the information that’s recorded in the RunSummary tab. Uh… the run will terminate when the Magma and Wallrock temperatures reach thermal equilibration – we can see that that happens here in rows 121 and 122. And, the run is finished!

**16:36**

So in the next tab – it’s labeled “ChartTAS”, in this tab you’ll find a generated Total Alkali & Silica diagram, complete with the results of the run. So not only is this nice because we’ve done the work for you, but the starting and ending temperatures of the run, here – 1174 for the liquidus temperature, and 881 for the final temperature - are recorded on the chart. In the next tab, “ChartMassFrac” (I’ll zoom in here just a smidge), we’ve provided another chart that we often find useful in the phase equilibria world - so this is a Total Mass Fraction Diagram. The Magma Chamber Simulator automatically takes the results of your model, and gives you the mass fraction for each phase in the run – liquid included – at each temperature step throughout the run. “ChartPPD” in the next tab is quite similar to the Total Mass Fraction diagram, but it records the phase proportions as a percent instead of a mass fraction. “Chart PMD” contains the same data as the Total Mass Fraction diagram, but if you look closely, you’ll see that the *cumulative* mass of all the cumulates (say that three times fast) gets recorded. I find this is a really nice way to illustrate the results of an entire system, and I need to give a hat tip to the incomparable Von Zeff for coming up with the code to construct these plots, because doing it by hand is the absolute **worst**.

**18:13**

Our final “Charts” tab reproduces the major element variation diagrams that we watched evolve during the run. So by default, we’ve got a first set of Harker diagrams (with wt.% SiO2 on the x-axis) and then if you scroll on down… waaayyyy down… we have some Fenner plots (with wt.% MgO on the x-axis). But you can actually change these to *whatever* you want. So let’s say, for example, that you want to look at how the major elements vary with wt.% H2O. When you’re putting together the MES Input file, scroll down to the *very* bottom. So I can show you here using the “Input” tab – if we scroll down to the very bottom, down past the 5th recharge event here… you can actually change what the axes are in each plot here in Row B. So instead of saying “Magma/SiO2”, you would put that to “Magma/H2O”, and that would be your new x-axis for graph 9. So this is super, super convenient, because you might not need a publication-quality Harker diagram, but we’re all definitely going to want to look at our data, and it’s just really nice if the plots are already made for you, and you don’t have to go through that extra step.

**19:43**

The “SolidFormulas” Tab is next. And in this tab, the composition of every mineral phase crystallized at every temperature decrement is recorded. You’ll notice that the formulas are completely written out in terms of their cations on the basis of *n* oxygen, which is sort of nice if you just need to estimate what compositional changes are going on. If you are, however, in search of the major oxide compositional data for these mineral phases, that information is actually recorded by the melts.tbl files generated during the run, and you can access that in the MCS folder structure. So if you want to get to that, in the MCS Folder (if we can go back…), here we have a folder labeled “Magma”, a folder labeled “Recharge”, and a folder labeled “Wallrock”. So the MELTS output files for each system are found here in these folders. If you wanted to know the composition of orthopyroxene in the wallrock, we could open up the orthopyroxene.tbl file (redo the absolute lovely formatting…) and now we can access this data. So now we have the compositional information for that mineral, at each temperature decrement.

**21:12**

The final two tabs contain raw data that the MCS uses to generate the Charts in the previous tabs. So we’ve made the raw data easily accessible in case you’d like to make your own diagrams: the “XChartDiagramsData” tab contains the data we use to make the mineral proportion diagrams, and then the “XChartData” tab contains the raw data used to make the major oxide variation diagrams. So this concludes our tutorial on how to interpret a Phase Equilibria Output File generated by the Magma Chamber Simulator. In our next tutorial, we’ll cover how to use the MCS’ different Recharge functions.

**21:58**