Introduction

In this second example involving laminae, LVPM was used to model limestone laminae whose pores alternately contain oil and montmorillonite. Both laminae types had bed thicknesses that varied from 0.01 cm to 10 cm. Both these laminae were oriented **parallel or perpendicular** to the neutron/gamma propagation direction. In this example, significant differences do appear between these two laminar orientations.

The oil and limestone had a 20% porosity with a matrix density of 2.71 g/cc and a matrix absorption cross section of 7.1 CU. The LVPM default oil was again $C_{12}H_{26}$ with a density of 1.05 g/cc. **The limestone pore size was fixed at 0.0001 cm.**

The montmorillonite was again $Ca_7Na_7Al_{12}Mg_4Fe_4Si_8O_{28}H_{12}B_{0.058978}$, with a density of 2.5 g/cc and intrinsic capture cross section of 60.0 cu. The montmorillonite completed filled the limestone pores at a porosity of 40% and **the limestone pore size was fixed at 0.1 cm**. The same limestone, with a density of 2.71 g/cc and cross section of 7.1 CU, was used for these laminae.

Heterogeneous Mode Results for Material1 or Material2

When LVPM is run in Heterogeneous Mode, there results two sets of OUTPUTS for two independent (infinite) media with small, but finite pore sizes. Bed thicknesses are not used in this mode. However, pore size effects do occur. Here are just a few of these OUTPUTS:

	LIME + MONT.		**LIME + OIL**	
	HOMO	**HET**	**HOMO**	**HET**
RHOB(g/cc)	2.626	2.569	2.378	2.383
DPHI	0.049	0.083	0.194	0.191
NPHI	0.050	0.050	0.361	0.360

In this context, homogeneous means that both materials are treated classically with infinitesimal pore sizes and heterogeneous refers to the LVPM modeling of their pore sizes. Because the pore sizes are quite different, the homogeneous and heterogeneous output values are different - these differences also show up between the parallel and perpendicular laminar orientation outputs.

Parallel and Perpendicular Mode Results for Material1 and Material2

In this mode, LVPM treats Material1 and Material2 as parallel or perpendicular laminae. The first six figures here detail the effect of (oil and limestone) and (montmorillonite and limestone) bed thickness variations on bulk density, density porosity, neutron porosity, thermal neutron diffusion length, thermal neutron diffusion coefficient, and neutron slowing down length. In this context, homogeneous refers to use of the standard mixing rules (outlined elsewhere) that including both infinitesimal pore sizes and classic bed thickness weighting and heterogeneous refers to pore size and bed thickness effects supported solely by LVPM.

In these figures, the far left always refers to mainly montmorillonite saturated limestone and the far right refers to mainly oil saturated limestone.

Specifically, from left to center, the limestone and montmorillonite bed thickness is fixed at 10 cm; then from center to right, this bed thickness drops from 10 cm to 0.01 cm. For the limestone and oil, its bed thickness varies from 0.01 cm to 10 cm from left to center and then from center to right, it is fixed at 10 cm.

According to Figure **1**, LVPM bulk density decreases with increasing oil and limestone laminae bed thickness and then continues to decrease as the montmorillonite and limestone bed thickness is reduced. Note that the homogeneous/classic bulk densities and the LVPM parallel orientation bulk densities are about the same whereas the LVPM perpendicular orientation bulk densities are much lower, by an average of 0.047 g/cc, than the other two. In this example, bulk density log readings in perpendicular and parallel laminated beds need to be increased to correct for the propagation of gamma rays in these laminae. For the parallel laminae these increases are equal to those expected from classic bed thickness weighting. However, for the perpendicular lamine, such corrections are much larger.

Figure **2** shows these features echoed in the density porosity. Notice that density porosity increases as the oil and limestone bed thickness increases: these density porosities are optimistic and must be decreased to improve accuracy. Again, note that the density porosity continues to increase as the montmorillonite and limestone bed thickness is reduced. LVPM results indicate that the decreases needed are much larger for the perpendicular case than might be expected from classic bed thickness weighting.

Increases in LVPM neutron porosity in laminated beds are observed in Figure **3** as the oil and limestone bed thickness increases; these increases continue as the montmorillonite and limestone bed thickness is reduced. These porosity values are derived from a proxy model based on the neutron slowing down length (Figure **6**). In this example, LVPM neutron porosities for both the parallel and perpendicular cases are about the same and both are larger than those predicted from classic bed thickness weighting. These overly optimistic porosity values must be decreased to improve porosity measurement accuracy.

Figures **4 through 6** detail results for the thermal neutron diffusion length and diffusion coefficient and also for the neutron slowing down length. For all three of these important neutron parameters/outputs, the standard mixing rules based on bed thickness weighting fail to make accurate predictions in both parallel and perpendicular cases. In this example, it is interesting to note that the thermal neutron diffusion length has a broad minimum in its behavior as a function of bed thicknesses.

Figures **7** and **8** detail the impact of LVPM calculations on bulk density-neutron porosity and density porosity-neutron porosity cross plots. (These figures are being revised to include a full range of bed thickness variations. More complete discussion will be given at that time)