

## Application Note

# The effects of field strength on NMR measurements

### Introduction

Traditionally, low field NMR instruments (operating at around 2 MHz) have been popular for use in petrophysics laboratories as they compare favorably, and reliably, to downhole NMR log data. In addition, the lower field also reduces the effect of high magnetic susceptibility of core samples compared to measurements in higher field instruments. However, higher field instruments present several distinct advantages including faster scan times for a given signal-to-noise ratio (SNR), and superior detection of short relaxation elements due to their shift to longer relaxation times.

Due to these advantages, higher field instruments have become more popular in recent years for use in core analysis. As instruments operating at different fields become more prevalent, it is important to understand how  $T_2$  distributions and  $T_1$ - $T_2$  maps vary with field strength. Without this understanding  $T_2$  distributions and  $T_1$ - $T_2$  maps recorded on the same sample could be interpreted differently when recorded at various fields.

### Effects of different magnetic fields

This application note examines the effect of different magnetic fields on  $T_2$  distributions and  $T_1$ - $T_2$  maps recorded on different sample types (bulk fluid, shale and sandstone). Each sample was scanned at the magnetic fields of 2 MHz, 12 MHz and 20 MHz. To make comparing the data recorded at each field straightforward, each  $T_2$  distribution and  $T_1$ - $T_2$  map were recorded with the same parameters and to the same SNR. Table 1 summarizes the observed volume, SNR and scan time for each sample studied. From the data it is obvious that the higher field instruments significantly reduce the scan time required to reach the same SNR. For example, for the bulk sample, the  $T_1$ - $T_2$  map took 1440 mins at 2 MHz but only 4.9 mins at 20 MHz. That is a 288x reduction in scan time.

Figures 1, 2 and 3 show the  $T_2$  distributions and  $T_1$ - $T_2$  maps measured for the bulk fluid, shale and sandstone samples respectively. The upper panel in each figure shows the  $T_2$  distributions measured at 2, 12 and 20 MHz while the lower panel in each figure shows the  $T_1$ - $T_2$  map at each field.

Sample	Field	Test	Volume (ml)	SNR	Scan Time (mins)
Bulk Fluid	2 MHz	$T_2$	6.31	4767	51.0
		$T_1$ - $T_2$	6.35	4418	1440
	12 MHz	$T_2$	5.94	5805	1.5
		$T_1$ - $T_2$	6.15	4812	33.0
	20 MHz	$T_2$	6.67	4844	0.18
		$T_1$ - $T_2$	6.67	4415	4.9
Shale	2 MHz	$T_2$	0.280	181.5	105.0
		$T_1$ - $T_2$	0.258	165.6	2895
	12 MHz	$T_2$	0.284	189.4	0.72
		$T_1$ - $T_2$	0.289	179	22.0
	20 MHz	$T_2$	0.291	181.5	0.12
		$T_1$ - $T_2$	0.291	165	4.5
Sandstone	2 MHz	$T_2$	2.54	884	63.5
		$T_1$ - $T_2$	2.59	808	1597
	12 MHz	$T_2$	2.60	1033	0.62
		$T_1$ - $T_2$	2.70	1355	32.7
	20 MHz	$T_2$	2.64	881	0.4
		$T_1$ - $T_2$	2.65	768	8.6

Table 1 - The observed volume, SNR and scan time for each sample studied.

The data presented in Figures 1, 2 and 3 clearly show that working at higher field has its benefits including improvement of the SNR, a shift of the shortest  $T_2$  components to longer values making them easier to detect, and a better separation between the signal on and off the 1:1 axis in  $T_1$ - $T_2$  maps. These improvements with higher field are particularly helpful when working with shale, or unconventional samples. Shale samples often have reduced pore volumes leading to poor SNR, small pores with short  $T_2$  values, signal from both light hydrocarbons and water on the 1:1 axis, and heavy organics with signal off the 1:1 axis.

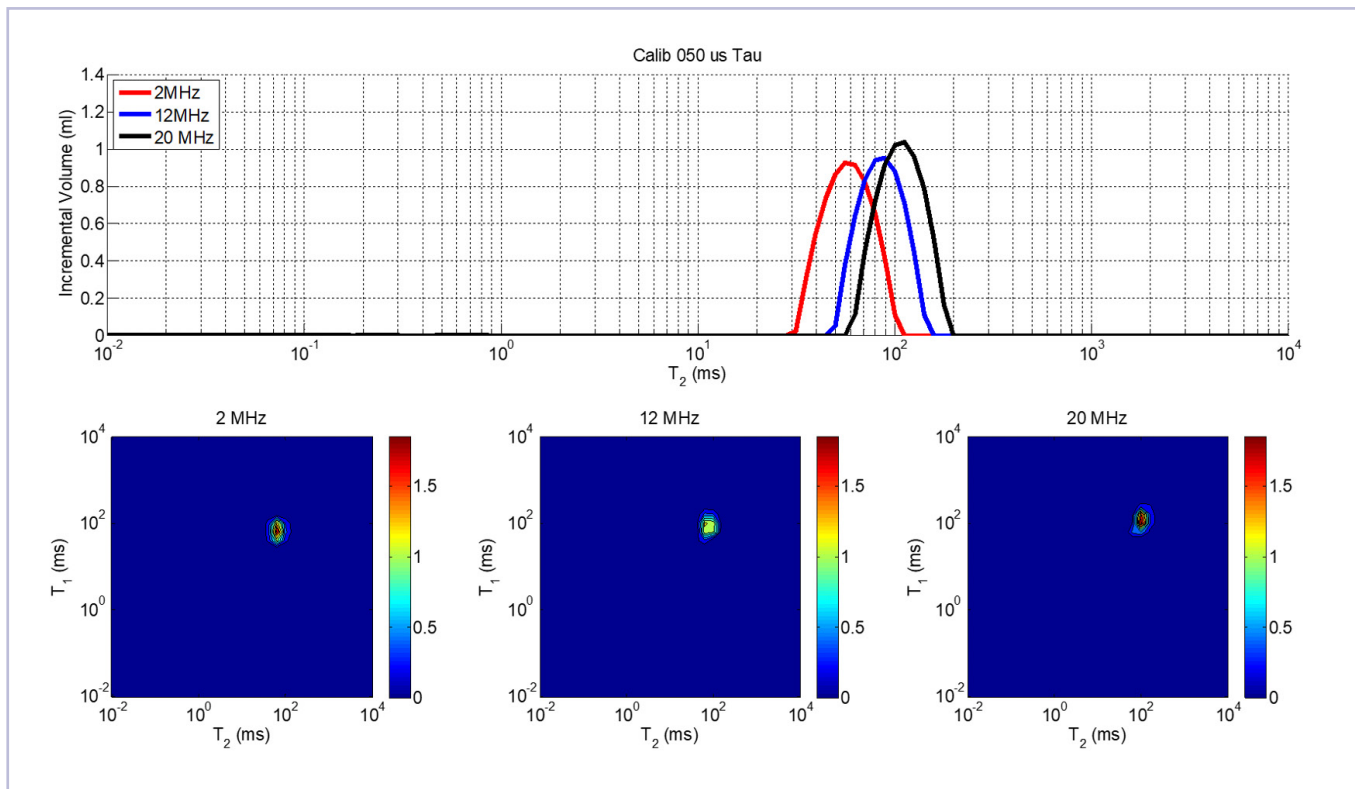


Figure 1 -  $T_2$  distributions and  $T_1$ - $T_2$  maps for a bulk fluid sample. The upper panel shows that the peak of the  $T_2$  distribution shifts to higher values as the field strength is increased. The same shift to higher  $T_2$  values with increasing field strength is also seen in the  $T_1$ - $T_2$  map shown in the lower panel.

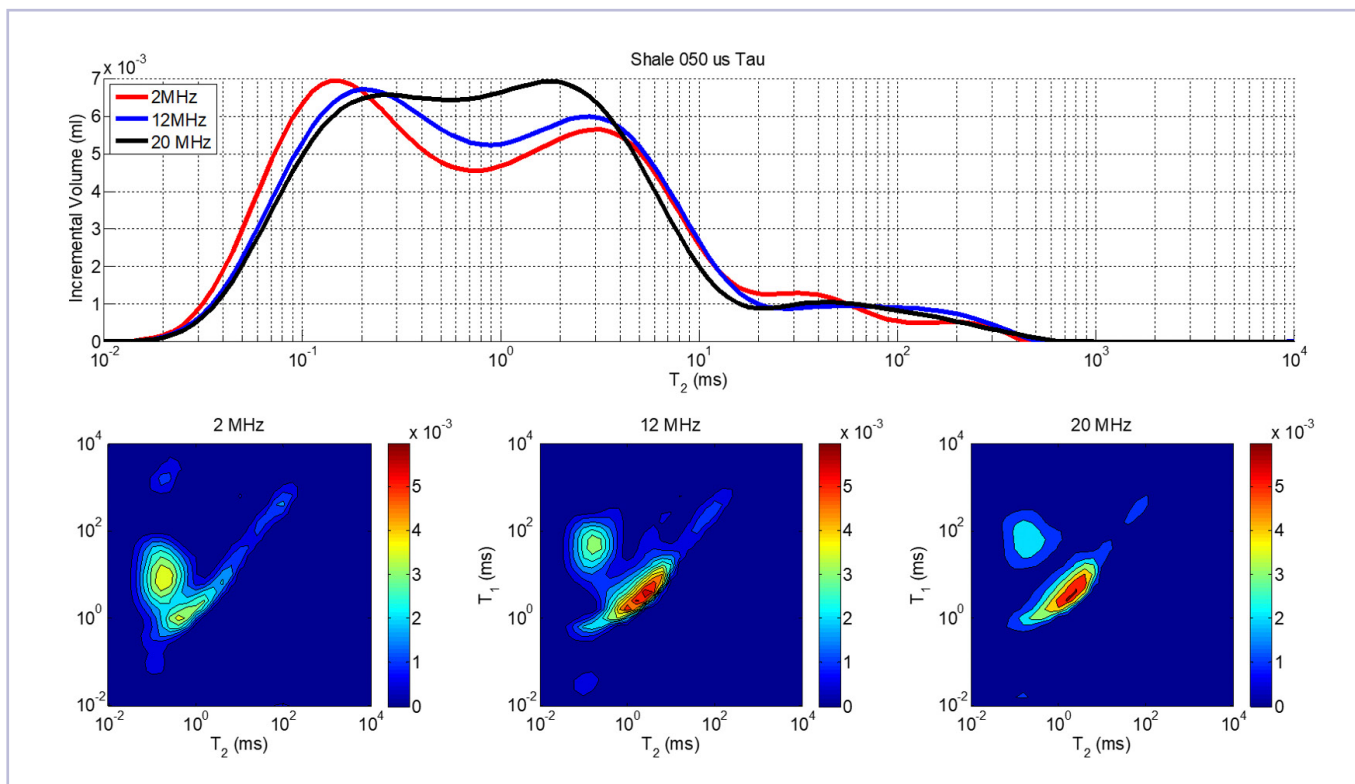


Figure 2 -  $T_2$  distributions and  $T_1$ - $T_2$  maps for a shale sample. The  $T_2$  distributions (upper panel) shifted to higher values with increasing field strength. The higher fields also increased the separation between the peaks on the 1:1 axis and those off axis in the  $T_1$ - $T_2$  maps (lower panels). This separation on  $T_1$ - $T_2$  maps makes it easier for water and light hydrocarbons (on 1:1 axis) to be distinguished from heavier components such as bitumen (off 1:1 axis).

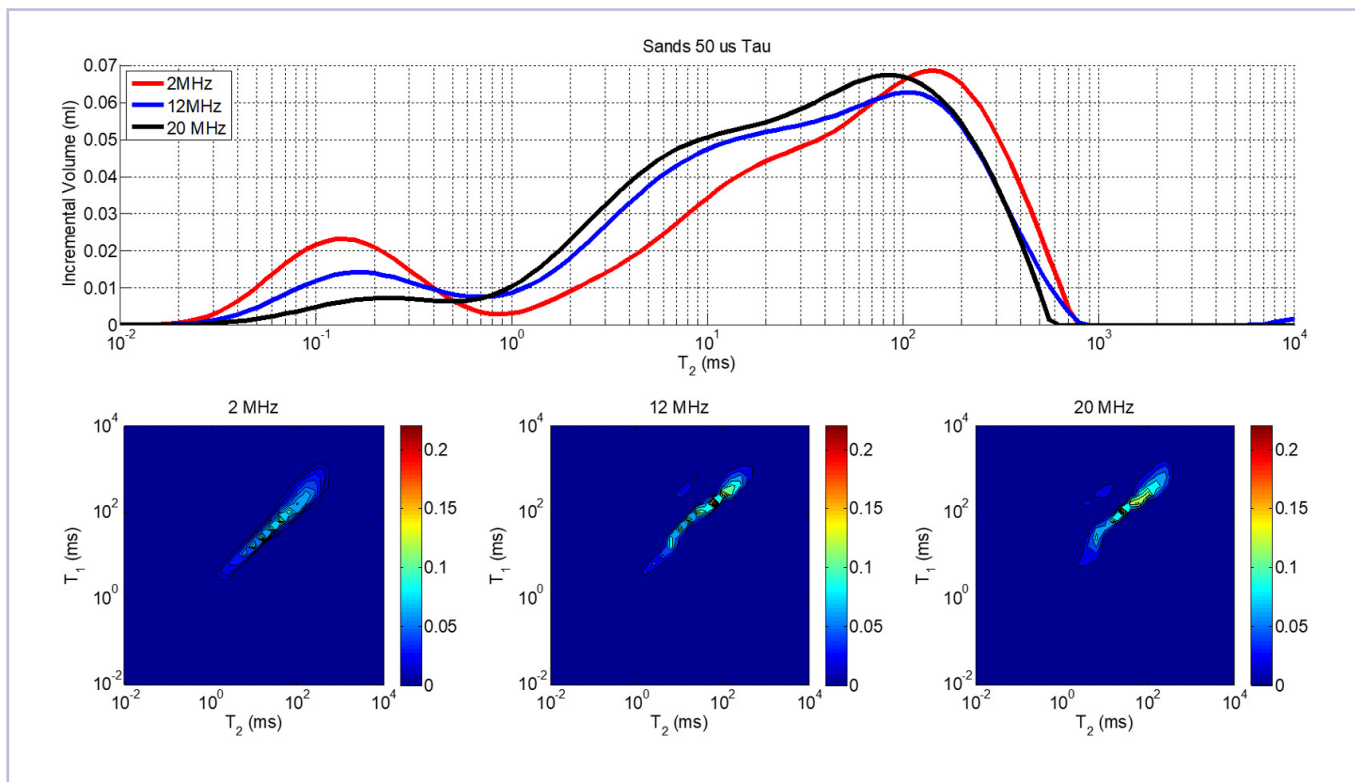
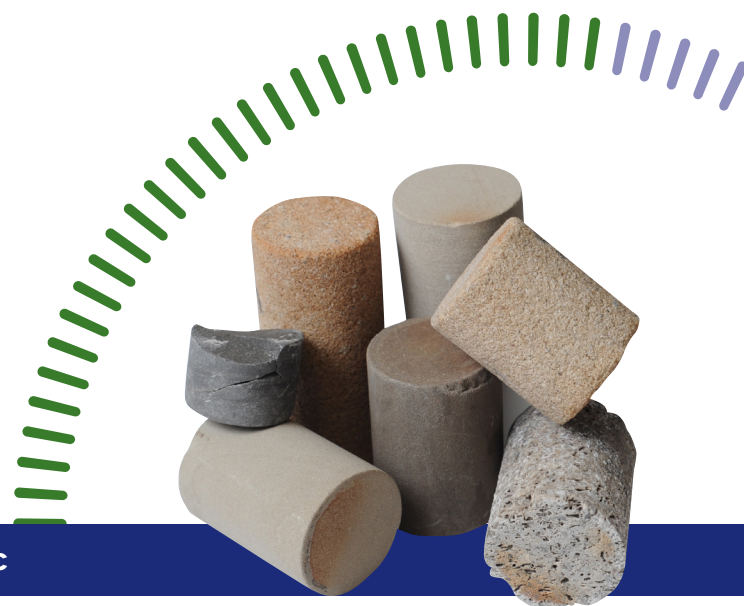


Figure 3 -  $T_2$  distributions and  $T_1$ - $T_2$  maps for a sandstone sample. The  $T_2$  distribution (upper panel) shifted to longer values. This is obvious from the size of the peak near 0.15 ms which decreases as the field strength is increased. A similar shift to higher values is also seen along the  $T_2$  axis for the  $T_1$ - $T_2$  maps (lower panel).

## Conclusion

The benefits of higher field NMR instruments, particularly from higher SNR and easier  $T_2$  component detection, often outweigh the disadvantages. Hence the increased popularity of 12 and 20 MHz instruments among rock core analysts in recent years. The drive to develop shale reservoirs and other unconventional reservoirs is driving interest in higher field instruments due to their ability to measure the small pores, and organic content (bitumen, kerogen) often present in these reservoirs. The interest in higher field has now spread to studies of all reservoirs due to the ability to produce more useful 2D correlation maps and other applications.



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