Green Imaging

OXFORD INSTRUMENTS

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.

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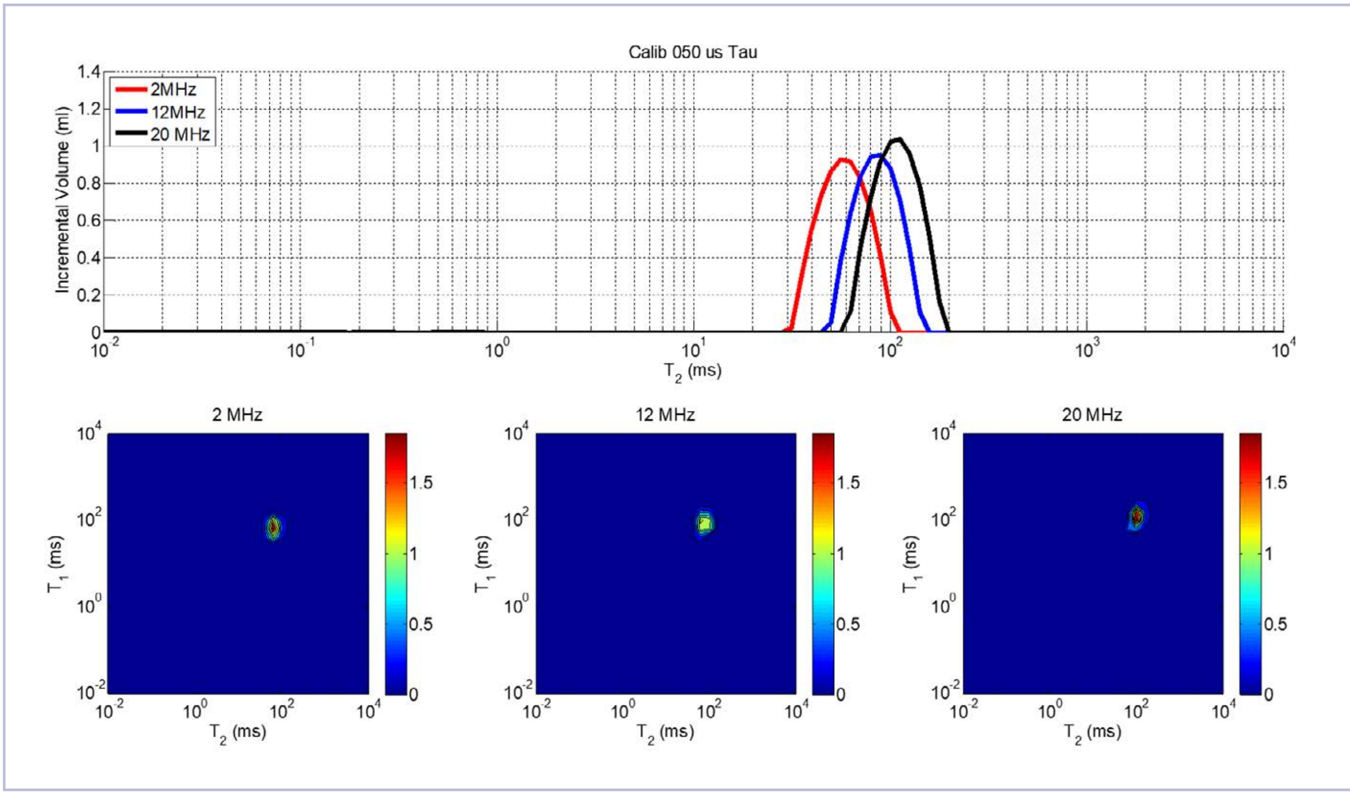

Figure 1 – T_2 distributions and T_1-T_2 maps for a bulk fluid sample. The upper panel shows that the peak of the T_2 distribution shifts to higher values as the field strength is increased. The same shift to higher T_2 values with increasing field strength is also seen in the T_1-T_2 map shown in the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

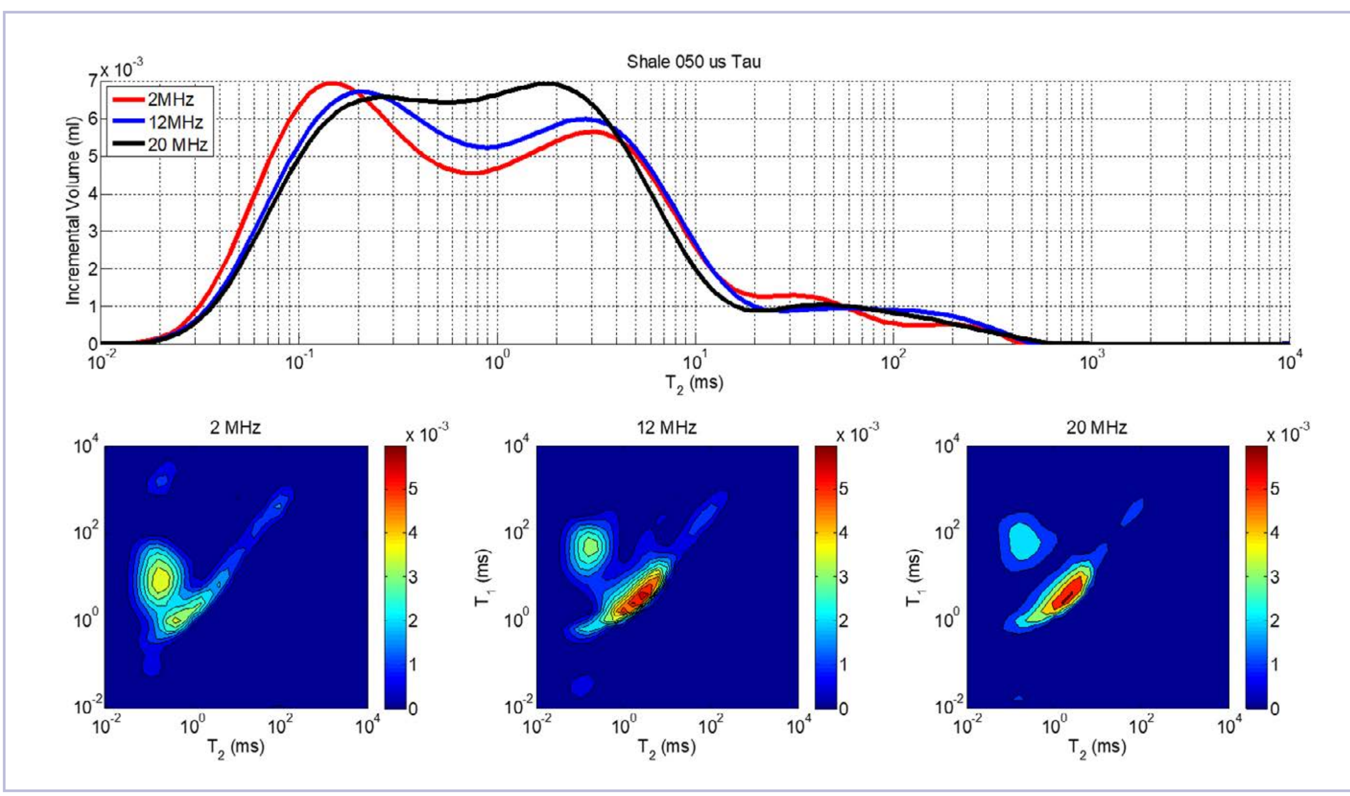

Figure 2 - T_2 distributions and T_1-T_2 maps for a shale sample. The T_2 distributions (upper panel) shifted to higher values with increasing field strength. The higher fields also increased the separation between the peaks on the 1:1 axis and those off axis in the T_1-T_2 maps (lower panels). This 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).

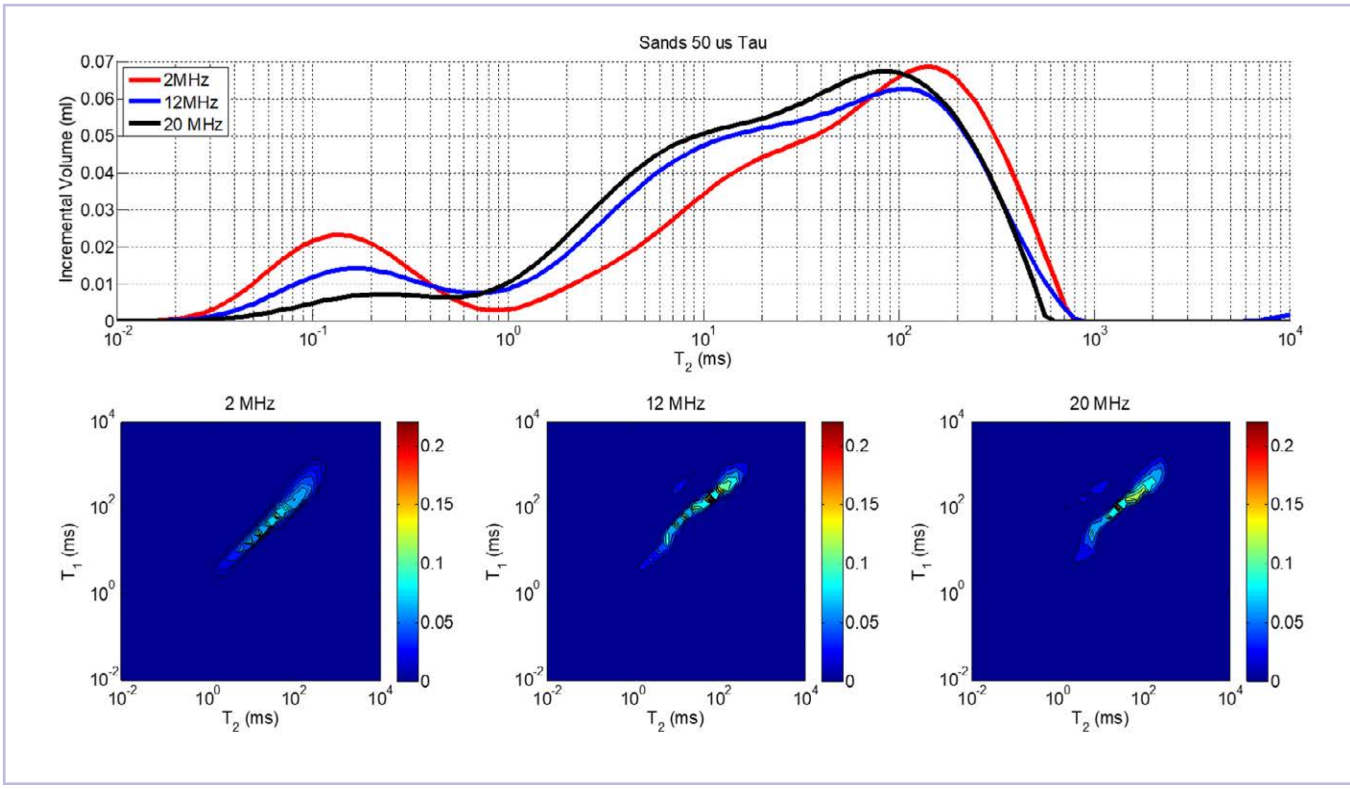

Figure 3 - T_2 distributions and T_1-T_2 maps for a sandstone sample. The T_2 distribution (upper panel) shifted to longer values. This is obvious from the size of the peak near 0.15 ms which decreases as the field strength is increased. A similar shift to higher values is also seen along the T_2 axis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