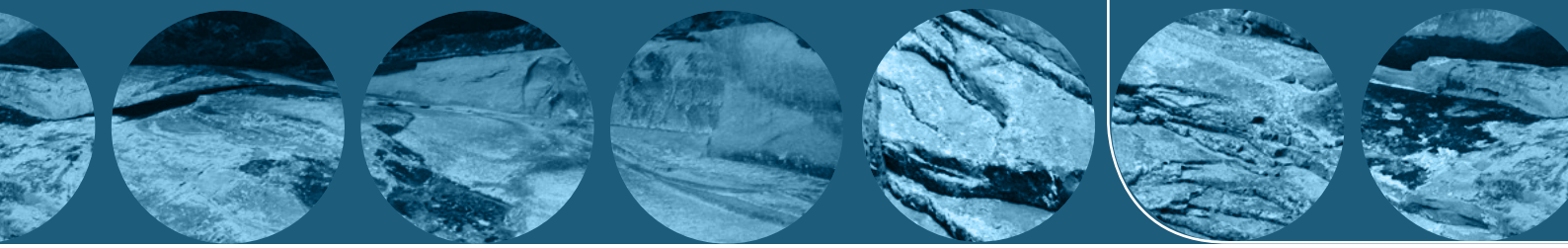
Rock core NMR - 12MHz versus 2MHz: Why go to higher field?

Technical Paper



Rock core NMR - 12MHz versus 2MHz: Why go to higher field?

Nuclear Magnetic Resonance (NMR) laboratory based core analysis has been performed for over 20 years, and for much of that time most of the measurements have been carried out at 2MHz. Laboratory based NMR rock core analysis was first devised to calibrate well logs which were collected using down hole NMR tools that operated at 2MHz, so it made sense to use 2MHz instruments in the laboratory. In recent years, as laboratory based NMR has expanded its tool box of measurements beyond well log measurements, and as more unconventional rocks are scanned, the tendency to use 2MHz is changing.

The sensitivity of NMR instruments increases with operating frequency, such that sensitivity at 12MHz is more than 10 times that at 2MHz, making measurements up to one hundred times faster. While the minimum echo spacing, and thus the smallest detectable pore size, are very similar for 12MHz and 2MHz instruments, the greater sensitivity of a 12MHz instrument means that adequate signal can be acquired from small pores in less time, with fewer scans

So, should users with 2MHz NMR benchtop systems upgrade to higher field instruments such as the 12MHz **GeoSpec+**? What are the advantages? This technical note will lay out the advantages of a 12MHz **GeoSpec** versus a 2MHz **GeoSpec** with the aim of answering these questions.

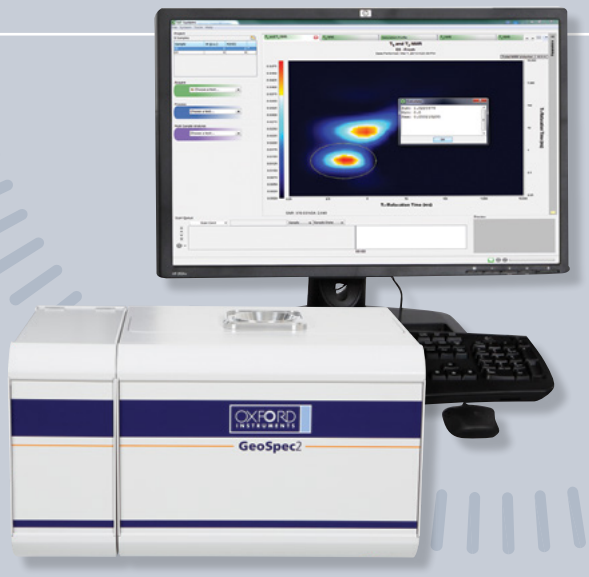
Method

The University of Oklahoma's Mewbourne School of Petroleum and Geological Engineering has completed a study comparing the 2MHz and 12MHz NMR responses, and much of this technical note is based on their findings.

To properly compare results, one must ensure the same samples are compared and that no alteration occurs to the sample between measurements. Table 1 overleaf shows the samples used in this comparison.[1]

The samples were scanned using a **GeoSpec** 2MHz rock core analyser and a **GeoSpec** 12MHz rock Ccore analyser, both owned by the University of Oklahoma.

continued overleaf



GIT GREEN IMAGING TECHNOLOGIES, INC.

OXFORD INSTRUMENTS
The Business of Science®

Rock core NMR - 12MHz versus 2MHz: Why go to higher field?

Samples	Porosity %	Permeability md
Berea Sandstone	19	157
Tennessee Sandstone	4	0.003
Lyons Sandstone	10	0.006
Fontainebleau Sandstone	7.2	25.5
Kansas Limestone	18	8.5
Fused Glass Beads	37	35,800
Aluminum Oxide	45	20,100
Eagle Ford Shale	6	-
Utica Shale	5	-
Woodford Shale	8	-

Table 1 *– Sample selection with porosity and permeability.*[1]

Method *continued*

All samples were cleaned using Soxhlet extraction at 100C, then dried in a vacuum oven for 12 hours, and finally saturated with dodecane at 7000psi for 48 hours.[1]

Signal to Noise (SNR) Comparison

If the same measurement time (number of scans) is used, the higher frequency of the 12MHz **GeoSpec** results in about 15 times more NMR signal being captured, meaning the SNR will be substantially higher. This is illustrated in Figure 1. As one would expect, high permeabiity samples have a higher SNR than low permeability samples.[1]

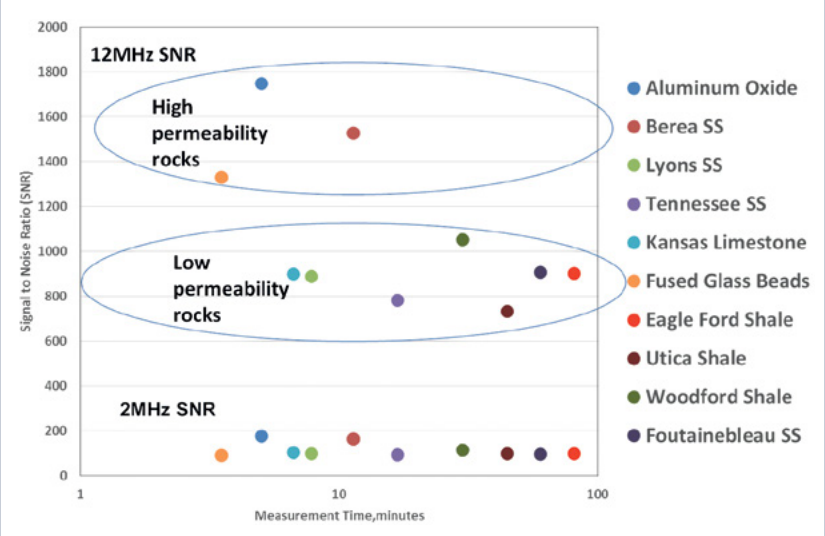


Figure 1 *– SNR vs measurement time. All data were collected with a TE of 300µs. The circled data are from the 12MHz system while the lower data points are from the 2MHz.*[1]

T_2 Spectra Shift

When comparing T_2 spectra measured at 2MHz with those measured at 12MHz, the 12MHz spectra can be seen to shift left and become better defined. The leftward shift can be explained by the fact that the higher frequency of the 12MHz **GeoSpec** causes faster relaxation of hydrogen protons at the pore walls, so the observed T_2s are shorter and the T_2 spectra shift left.

Figure 3 shows the T_2 spectra from the same sample measured at 2MHz and 12MHz and illustrates the spectra shift. In the Kansas limestone, the 12MHz spectra is bimodal, which can be attributed to the higher SNR of the 12MHz **GeoSpec**, resulting in better visibility of the smaller pores spaces.

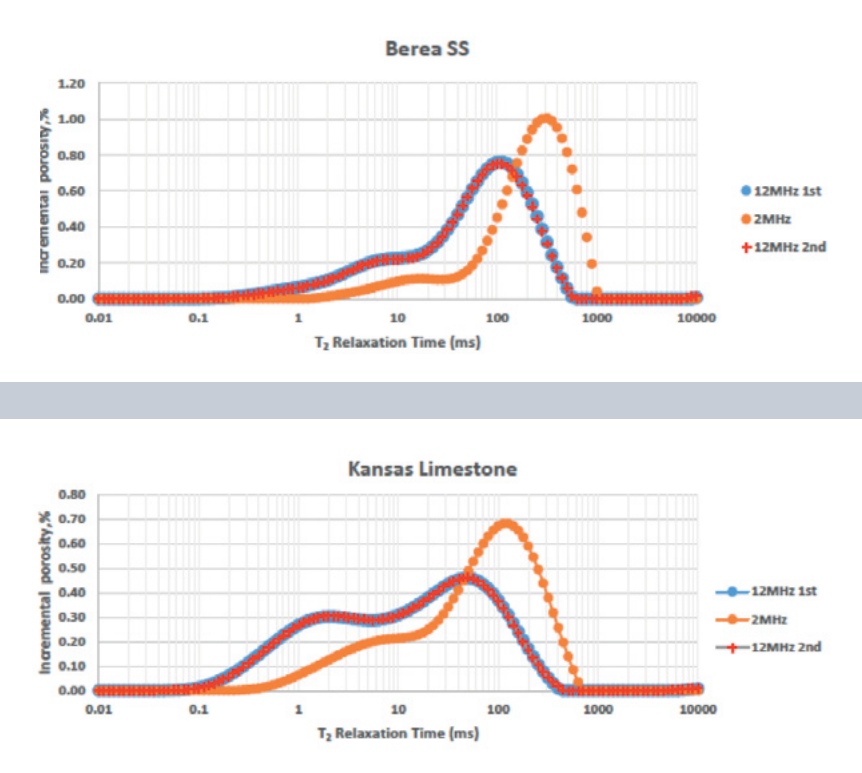


Figure 3 *– T_2 spectra of two samples measured at 2MHz and 12MHz at Tau=75us.*[1]

2D Correlation Maps

One of the key areas of interest in laboratory based NMR core analysis measurements in recent years has been 2D correlation maps, which measure two parameters and correlate them in a 2D map. The two most popular are the T_1-T_2 map and the T_2-Diffusion map. Both these maps are signal intensive and if one can measure at better SNR one gets better defined maps and gets them more quickly.

As seen above with the T_2 spectra shift, the 12MHz **GeoSpec** provides better resolution of the T_2 (and T_1) spectra, which means the correlation between the two in a T_1-T_2 map is better defined, or put another way, the data populations will be better separated and better defined on the maps. While 2D maps are have been produced successfully at 2MHz, the 12MHz **GeoSpec** instrument with Q-Sense probe technology offers exponentially better SNR and thus can measure these signal intense measurements more quickly and with better resolution. 2D map measurements not only require 4 times as much data as a 1D measurement, but also require the data to spread over a larger area due to the 2 dimensional nature of the measurement.

Conclusions

It has been determined in independent tests by Oklahoma University's Mewbourne School of Petroleum and Geological Engineering, that a 12MHz **GeoSpec** NMR rock core analyser can obtain an SNR that is an average of more than 11 times higher than the SNR obtainable on the 2MHz **GeoSpec**, in high porosity samples. In low porosity samples such as shales, using the same number of scans in each instrument, the SNR is an average of almost 9 times higher in the 12MHz instrument.

The 12MHz **GeoSpec** has distinct advantages over the 2MHz system in terms of signal to noise ratio. The vastly better SNR means measurements are acquired more quickly, and allow for better resolution in T_2 spectra, more accurate porosity measurements with tight rock cores, better defined 2D correlation maps, and use of a wider range of signal filters.

[1] Comparison of 2MHz and 12MHz NMR Responses in Conventional and Unconventional Reservoir Rocks. B. Min, C.H. Sondergeld, C.S. Rai, Society of Petrophysicists and Well Log Analysts

Oxford Instruments Magnetic Resonance

For more information: **magres@oxinst.com**
www.oxinst.com/geospec

UK

Tubney Woods, Abingdon, Oxfordshire, OX13 5QX, UK
Tel: +44 (0) 1865 393 200 **Fax:** +44 (0) 1865 393 333

USA

300 Baker Avenue, Suite 150, Concord, MA, 01742, USA
Tel: +1 978 369 9933 **Fax:** +1 978 369 8287

China

Floor 1, Building 60, No.461, Hongcao Road, Shanghai, 200233, China

Tel: +86 21 6073 2925 **Fax:** +86 21 6360 8535

Green Imaging Technologies

For more information: **info@greenimaging.com**
www.greenimaging.com

Canada

520 Brookside Drive, Suite B, Fredericton, NB, E3A 8V2, Canada

Toll Free: +1 888 944 8462
Tel: +1 506 458 9992 **Fax:** +1 506 458 9615

GIT GREEN IMAGING TECHNOLOGIES, INC.

OXFORD INSTRUMENTS
The Business of Science®

4819