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CITY AND COUNTY MUSEUM SITE, DANEGATE CARPARK, LINCOLN.

Report on ground penetrating radar survey, January 2003.

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'oduction

owing a request from the Dr Jim Williams, the English Heritage Regional Archaeological :ntific Advisor for the East Midlands, a limited GPR survey was attempted in the Danegate 'ark, in the centre of the Lincoln. The carpark (NGR TF 977 715), constructed in the 0s, is built on three storeys cut into the rising hillside below Lincoln cathedral and is :duled for demolition prior to the redevelopment of the site to house the new City and :nty Museum. Previous excavation conducted by Graham Webster in 1947 revealed the :ence of significant archaeological features, including substantial remains of the original nan city walls and the area is recorded as a scheduled ancient monument (SAM No. :oln 115). However, available site plans from the 1947 excavation fail to record any inent relocation information. Indeed, C18th and C19th buildings were deliberately luded from the excavation plan.

believed that the floor of the present carpark was constructed from a thin layer of non-forced concrete scree over a hardcore rubble base, sitting immediately above the ıaeological horizons identified by Webster. In this case, GPR survey might be expected to ıte the underlying archaeological remains providing interference from the current structure ot too obtrusive.

thod

'ial Ground Penetrating Radar (GPR) survey was conducted with a Pulse Ekko PE1000 sole and 225MHz centre frequency antenna. The 225MHz antenna was selected as the st suitable centre frequency for obtaining the optimum depth of penetration and lateral ›lution required to image the known archaeological targets. Attempts to estimate the ›city of the radar wavefront in the subsurface through a common mid-point (CMP) velocity lysis conducted in the field proved unsuccessful, due to interference from air-wave ections within the structure of the carpark. However, analysis of diffraction tails within the ıltant data confirmed the presence of both multiple air-wave reflections and additional, surface reflections with a velocity of ~0.09m/ns. This latter velocity was adopted as a ;onable average value for processing the data from this site and for the estimation of depth flection events in the recorded profiles. As these reflections are likely to represent the ·front travelling through the concrete floor and they may, therefore, overestimate the ty in the underlying layers.

of parallel traverses separated by 0.5m were established over two survey areas within r and middle decks of the carpark (Figure 1). Individual traces along each profile were by 0.05m and recorded the amplitude of reflections through a 150ns time-window. isition processing involved the adjustment of time-zero to coincide with the true l surface, removal of any low frequency transient response (dewow), noise removal and plication of a suitable gain function to enhance late arrivals (Figure 3).

ıttempt to suppress the interference from airwave reflections and their multiples data ıdjacent GPR transects were added together to produce a mean profile in a manner r to Carrozzo et al (in press). In theory, given a regular site geometry airwave reflections he east and west walls of the carpark should appear at similar locations within all the es. Such airwaves should sum together constructively within the mean profile that can e subtracted from the initial profile prior to further processing. Figure 3 demonstrates ıis process was only partially successful at the site due, no doubt, to the variable etry of the carpark structure. The interpretation of the amplitude time slice data presented ure 6 was made after comparison with both the airwave-suppressed and initial forms of ıta to avoid the mis-interpretation of processing artefacts.

o antenna coupling of the GPR transmitter with the ground to an approximate depth of ry near surface reflection events should only be detectable below a depth of 0.2m, ning a centre frequency of 225MHz and a velocity of 0.09m/ns. However, the broad width of an impulse GPR signal results in a range of frequencies to either side of the e frequency which, in practice, will record significant near-surface reflections closer to round surface. Such reflections are often emphasised by presenting the data as amplitude slices. In this case, the time-slices were created from the entire data set, after applying a ıigration algorithm, by averaging data within successive 8ns (two-way travel time) ows (David and Linford 2000; Sensors and Software 1996). Each resulting time slice, rated as a greytone image in Figures 4 and 5, represents the areal variation of reflection gth through successive ~0.4m intervals from the ground surface.

ılts

er deck

ırea of 27m × 18m was surveyed to encompass the expected location of the 1947 excavation determine the continuation of any significant archaeological remains. Regrettably, the data is ly compromised due to the presence of multiple airwave reflections from the carpark ture and secondary subsurface reflections from the walls and concrete piles supporting the er deck.

only significant anomalies within the data appear as a series of linear high/low responses ding approximately NS across the concrete deck of the carpark. Comparison with the al data (no attempt to suppress airwave reflections) confirms the presence of these ıalies at the same location through successive amplitude timeslices. This suggests that the ılies are neither due directly to airwaves nor to artefacts produced by the processing l to suppress these reflections. Had the linear anomalies been created by surface s then their location would be expected to migrate towards the centre of the survey ugh successively deeper timeslices (*cf* the relative position of the red arrows shown e 3(A)). It seems likely that these linear anomalies are related to the present carpark possibly some form of reinforcement within the concrete floor raft.

ldle deck

: geometry of the Middle deck survey area has proved more difficult for the suppression of vave reflections and their multiples, possibly due to the proximity of the solid wall to the This questions the fidelity of the apparently symmetrical responses indicated at [1]/[2], [4] and [5]/[6] on Figure 6, that may well all be due to a combination of airwave ections and later arrivals propagated through the concrete floor raft from the modern wall tings. However, anomalies [1] and [2] do occur at the suspected location of former torian cellars over which the carpark was later constructed.

ɔ tentative linear anomalies [7] and [8] are also found within the near-surface data ough these are most likely to be associated with modern service cables or utilities.

ıclusion

R survey has proved unsuccessful at this site despite the use of shielded antenna and itional post-acquisition processing to suppress airwave reflections from the carpark structure. vey with a higher centre-frequency antenna may well have limited the interference from vave reflections but at the expense of penetration depth. This latter consideration is of ortance as engineering boreholes, made available following the completion of the field work, cate a depth of between 4 to 6m of 'made ground' underlying the concrete floor raft in the nity of the lower deck survey area. Whilst such boreholes may not, necessarily, identify inct archaeological horizons it seems likely that any surviving remains could be ıpromised by the addition of hardcore introduced to level the site prior to the construction of carpark.

ddition, the linear anomalies identified within the lower deck survey area suggest some form einforcement has been introduced within the concrete raft further hampering the acquisition eliable GPR data. The possible identification of anomalies related to the cellars of former torian buildings constructed over the site in the middle deck survey area seems more likely, revious trial excavation within the survey area confirmed the survival of significant late on to late Medieval remains approximately 0.42m from the current ground surface p://www.lincolnshire.gov.uk/lccconnect/culturalservices/CCMuseum/Arch.htm).

veyed by:	N Linford L Martin J Williams	Date of survey:	30/01/2003
›rted by:	N Linford	Date of report:	19/02/2003

:ometry Branch,
Heritage Centre for Archaeology.

Acknowledgements

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References

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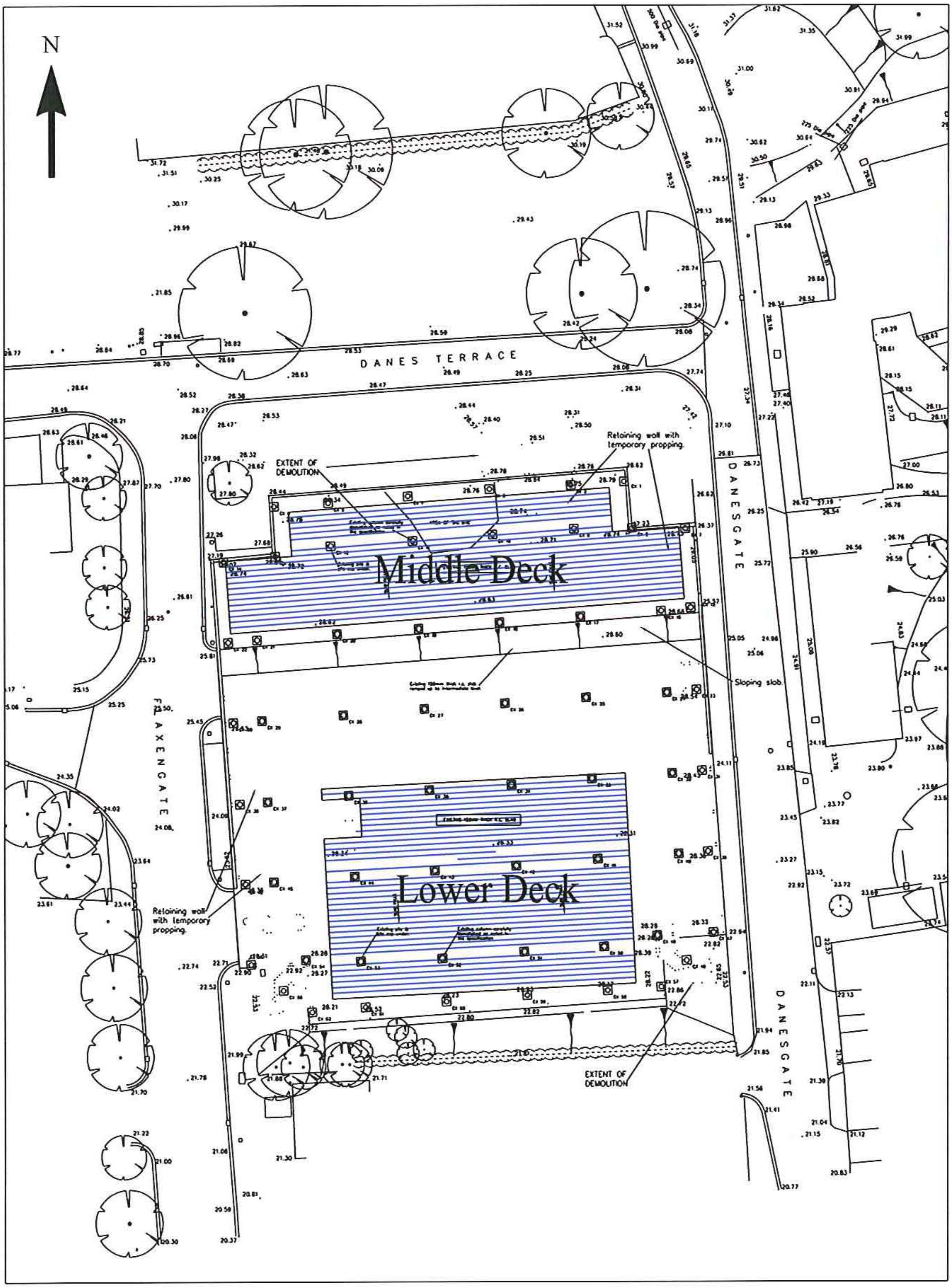
David, A. and Linford, N., 2000, Physics and Archaeology, *Physics World*, **13**, No. 5, pp27-31.

Sensors and Software, 1996, *pulseEKKO IV RUN User's Guide*, Technical Manual 20.

List of enclosed figures

Figure 1

DANEGATE CARPARK, LINCOLN
Location of Ground Penetrating Radar survey, January 2003



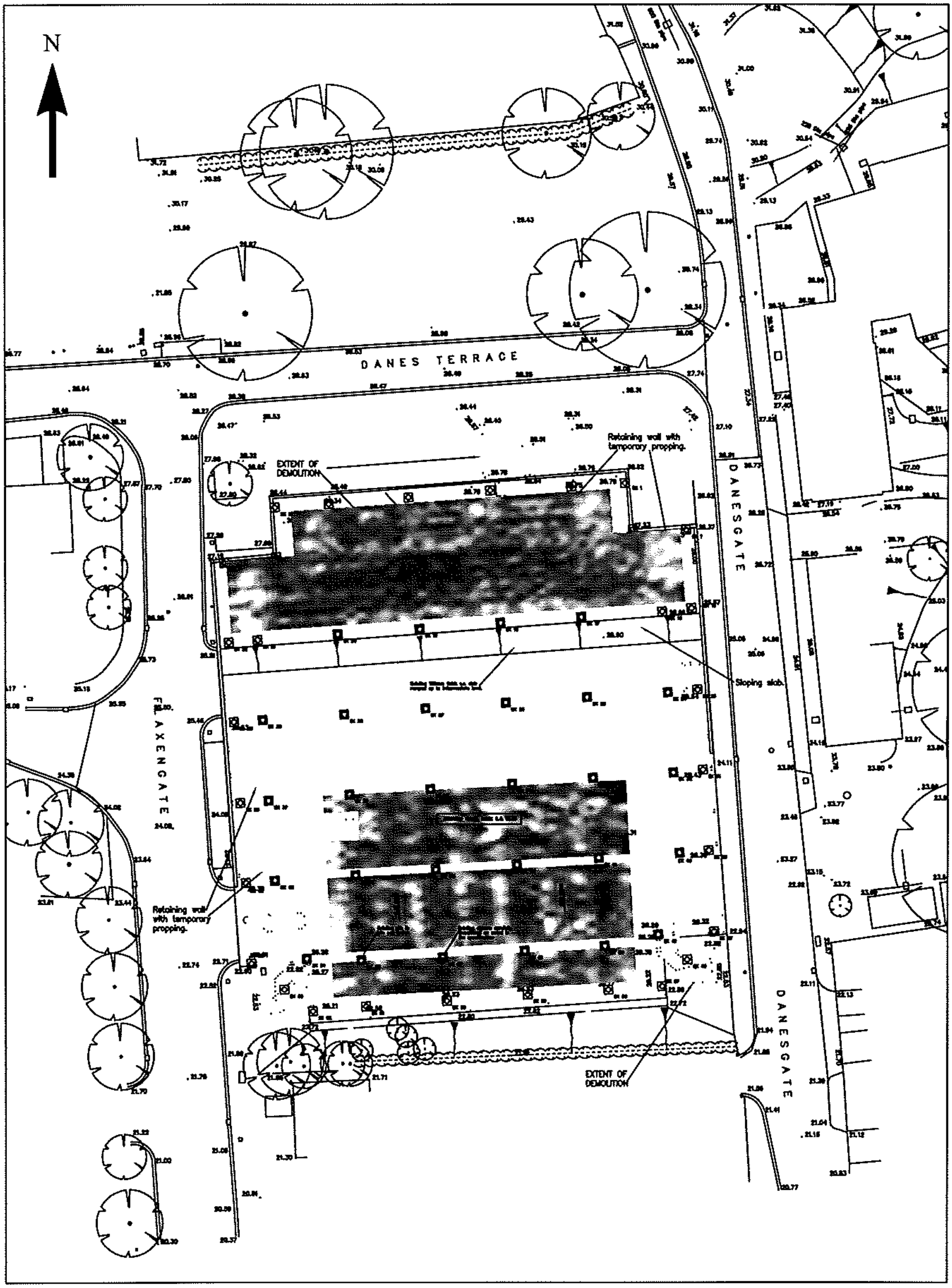
GPR Transect

0 15m
1:500

Figure 2

DANEGATE CARPARK, LINCOLN

Location of Ground Penetrating Radar survey, January 2003



GPR Amplitude timeslice 20 - 24ns (2.0 -2.4m)

0 15m

1:500

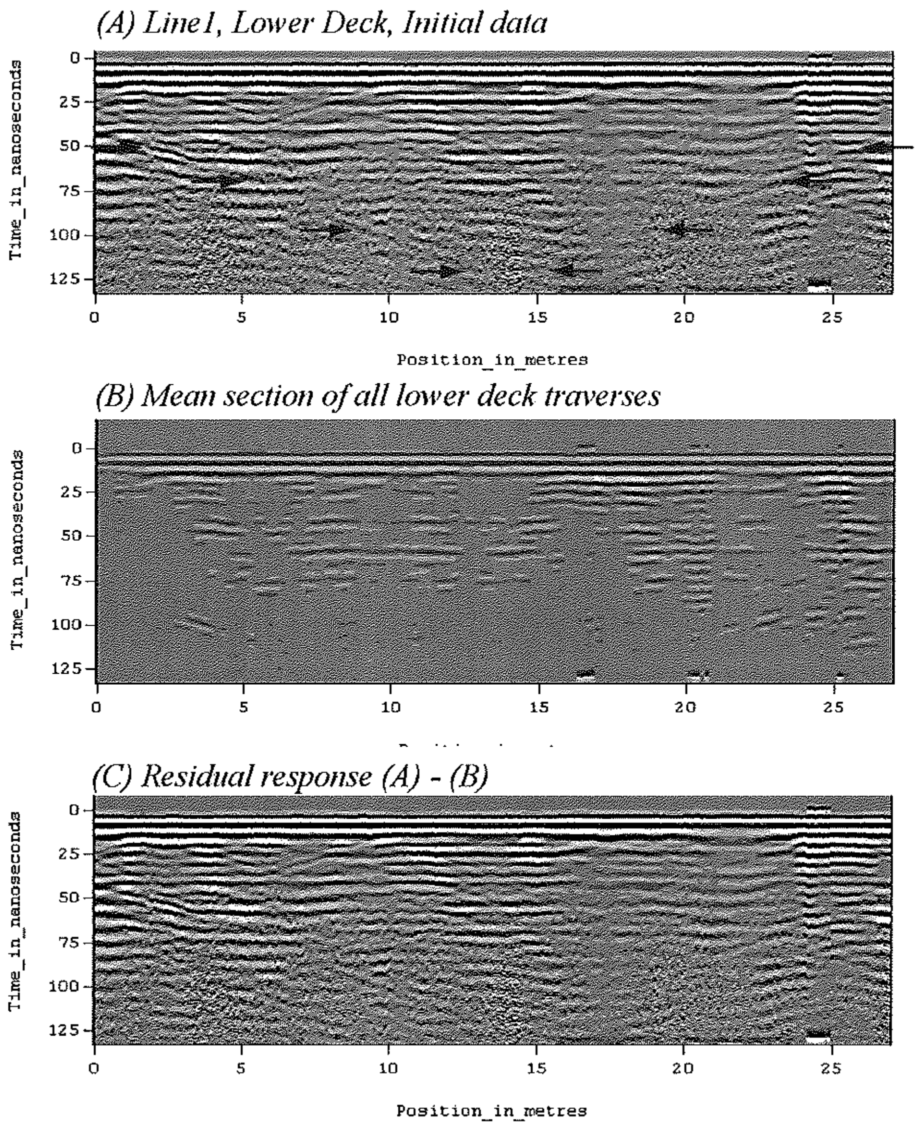
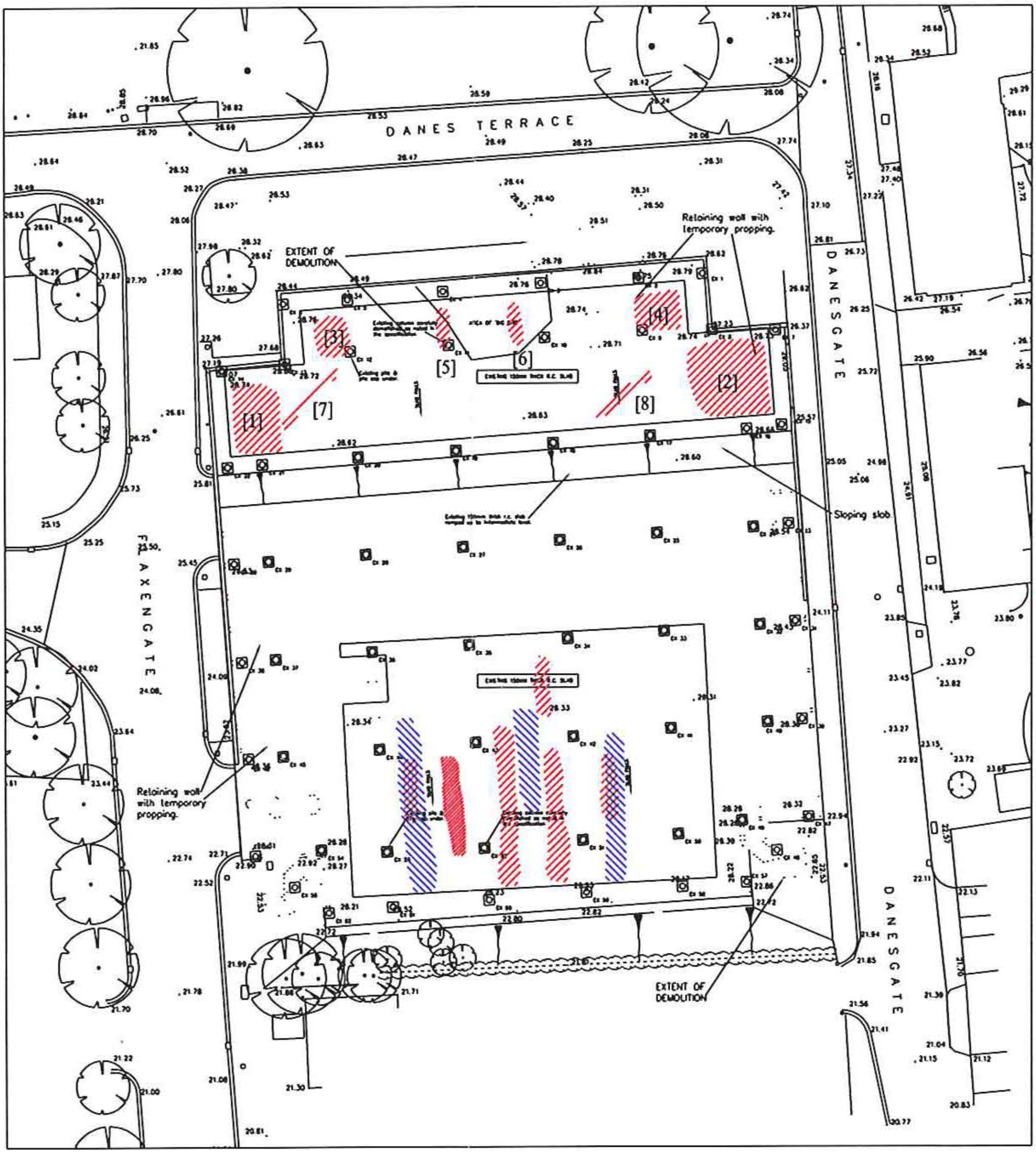


Figure 3; Danegate Carpark, Lincoln, *(A) initial GPR profile from the first line of the Lower Deck survey area, showing the influence of air-wave reflections (red arrows). The equalised sum of all the Lower deck profiles is shown in (B) in an attempt to characterise air-wave reflections from both the walls of the carpark and the supporting piles. The residual section following the subtraction of (A) from (B) is shown in (C).*

27/2003

Figure 6

DANEGATE CARPARK, LINCOLN
Summary of significant GPR anomalies



High amplitude reflection

Low amplitude reflection

0 15m
1:500

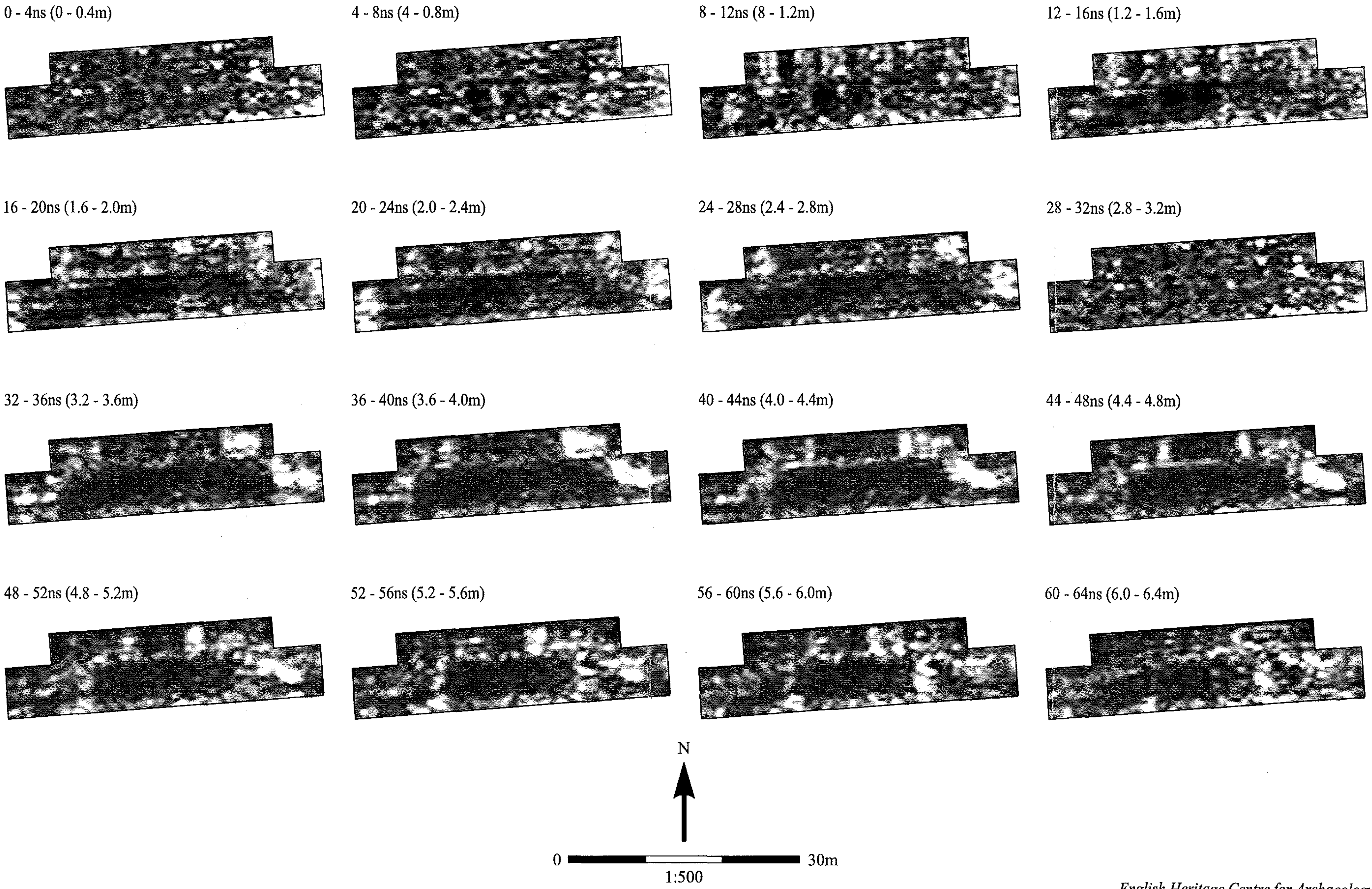
English Heritage Centre for Archaeology 2003

27/2003

DANEGATE CARPARK, LINCOLN.
Ground Penetrating Radar survey, January 2003

Figure 5

Amplitude Time Slices: Middle deck



English Heritage Centre for Archaeology 2003

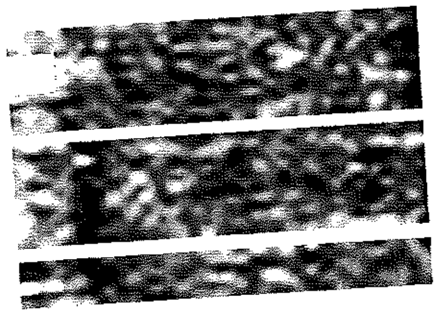
27/2003

Figure 4

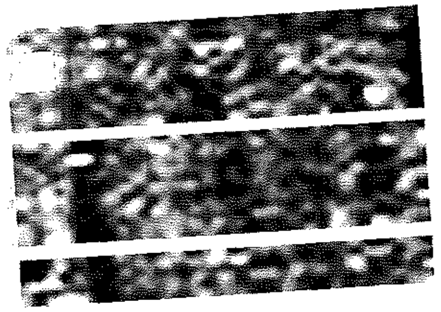
DANEGATE CARPARK, LINCOLN.
Ground Penetrating Radar survey, January 2003

Amplitude Time Slices: Lower deck

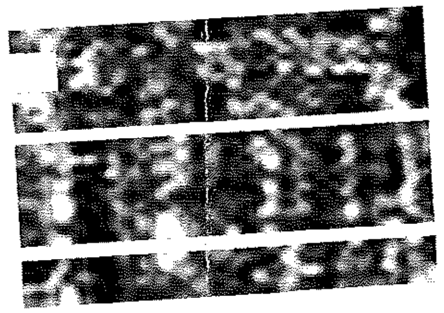
0 - 4ns (0 - 0.4m)



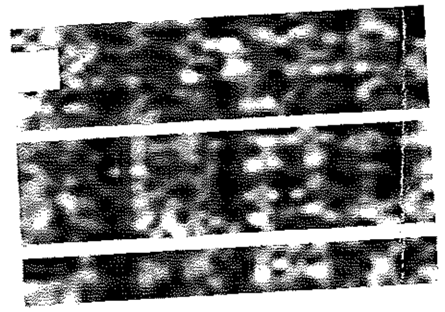
4 - 8ns (0.4 - 0.8m)



8 - 12ns (0.8 - 1.2m)

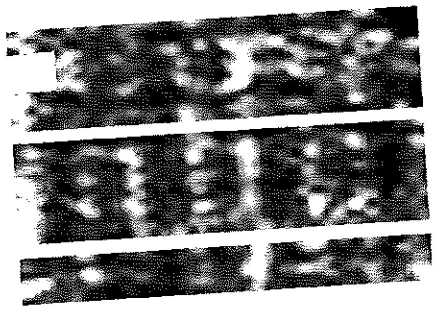


12 - 16ns (1.2 - 1.6m)

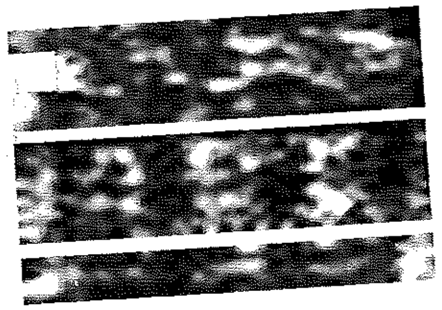


16 - 20ns (1.6 - 2.0m)

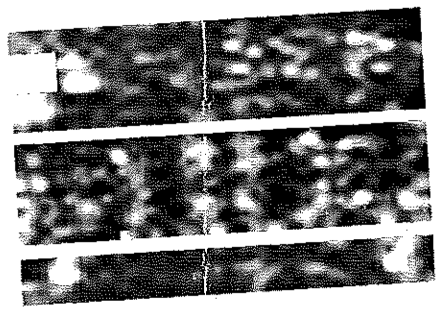
20 - 24ns (2.0 - 2.4m)



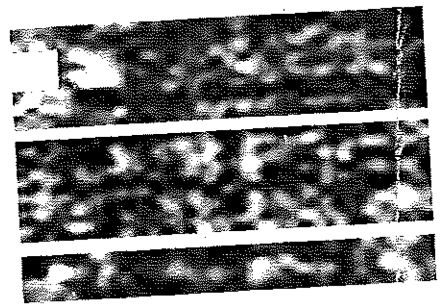
24 - 28ns (2.4 - 2.8m)



28 - 32ns (2.8 - 3.2m)

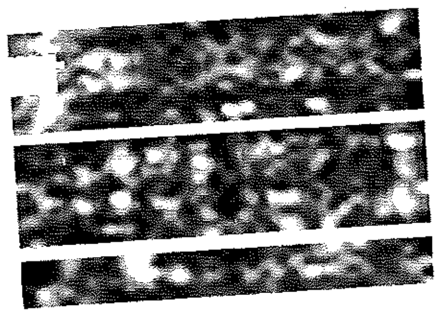


32 - 36ns (3.2 - 3.6m)

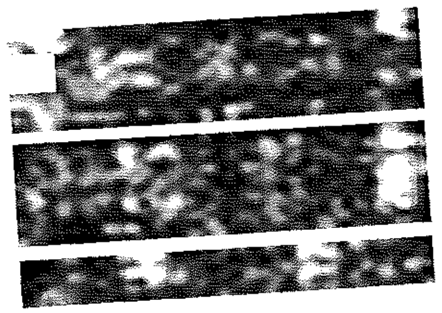


36 - 40ns (3.6 - 4.0m)

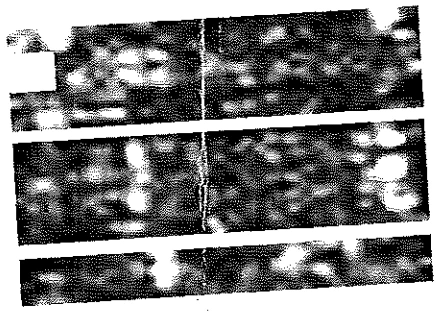
40 - 44ns (4.0 - 4.4m)



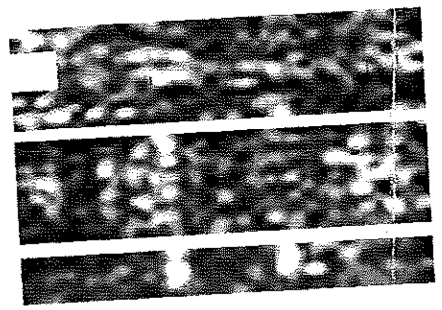
44 - 48ns (4.4 - 4.8m)



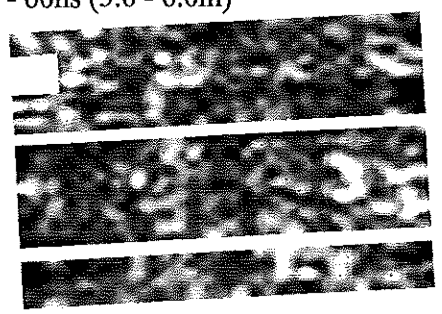
48 - 52ns (4.8 - 5.2m)



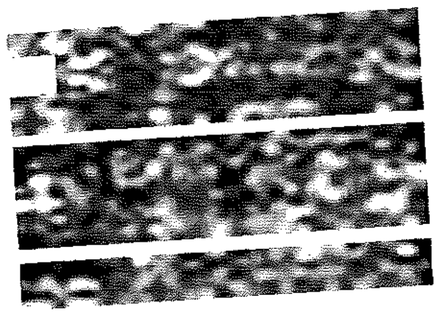
52 - 56ns (5.2 - 5.6m)

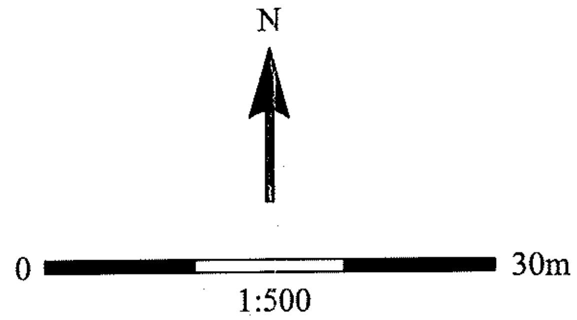


56 - 60ns (5.6 - 6.0m)



60 - 64ns (6.0 - 6.4m)





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