Multispectral Imaging and Ground-Penetrating Radar in the Search for Roman Roads: Capabilities, Limitations, and the Silver Bullet Question A companion study to LiDAR and the Roman Roads of Britain

ABSTRACT

This report examines two remote sensing and geophysical techniques — multispectral imaging and ground-penetrating radar (GPR) — as tools for identifying and characterising the courses of Roman roads in the British landscape. Drawing on the resources of the Roman Roads Research Association (RRRA), the citizen-science research of David Ratledge at Travelling with the Romans, and a body of peer-reviewed academic literature, it evaluates what each technique can and cannot do, describes the principal equipment used in British fieldwork, and assesses whether either method constitutes the "silver bullet" that researchers have long sought. The conclusion is that both techniques make transformative contributions in specific contexts — multispectral imaging in lowland arable landscapes, GPR in urban and subsurface investigations — but that neither is sufficient alone. The most productive research programmes combine both with LiDAR, aerial photography, magnetometry, and targeted excavation.

1. Introduction: The Limits of LiDAR and the Need for

Complementary Methods The publication of the Environment Agency's National LiDAR Programme data from 2015 onwards transformed the study of Roman roads in Britain. Researchers such as David Ratledge, whose county-by-county reappraisals are documented at twithr.co.uk, and the academic team of Parcero-Oubiña, Smart, and Fonte, whose 2023 paper in the Journal of Computer Applications in Archaeology mapped approximately 100 kilometres of new roads in Devon and Cornwall, demonstrated that LiDAR could detect the raised embankment (agger) and flanking ditches of Roman roads even where they had been invisible on the ground for centuries.1 Yet LiDAR has fundamental constraints. It cannot penetrate the soil; it requires a surviving surface expression; it is defeated by intensive arable ploughing in lowland landscapes; and it cannot authenticate the Roman date of any feature it reveals. These limitations make the case for two complementary approaches. Multispectral imaging — the capture of reflected electromagnetic radiation across multiple wavelength bands, extending beyond the visible spectrum into the near-infrared — can detect Roman roads in precisely the lowland arable contexts where LiDAR fails, by revealing the stress patterns that buried compacted road surfaces impose on growing crops. Ground-penetrating radar (GPR) — a geophysical technique that transmits electromagnetic pulses into the ground and measures the reflections from subsurface interfaces — can detect the physical structure of a road at depth, providing cross-sectional profiles, depth measurements, and subsurface confirmation that neither LiDAR nor multispectral imaging can supply. Together, these three methods form a powerful investigative toolkit; separately, each has significant blind spots.

2. Multispectral Imaging

2.1 The Physical Principle: Cropmarks and the Electromagnetic Spectrum

The detection of Roman roads by multispectral imaging rests on the phenomenon of the cropmark. When a Roman road is buried beneath arable land, its compacted stone and gravel metalling inhibits the downward growth of crop roots, reducing the moisture and nutrient supply available to plants growing directly above it. The result is a negative cropmark: a band of stunted, yellowing, early-ripening crop that traces the road's course from above. The flanking ditches, by contrast, which have filled over centuries with richer, deeper soil, produce positive cropmarks — bands of taller, greener, later-ripening crop. Together, these create a characteristic striped signature that can be read from the air as a linear feature crossing the landscape. As Historic England's guidance on cropmark formation explains, "compacted surfaces such as floors or Roman roads can inhibit growth," and the patterns created "can be observed from visible differences in crop colour and height during various stages of the growing season." The key physical variable is soil moisture: a lack of rainfall before and during the growing season exaggerates the differential growth effects, making features more visible. Well-drained soils on gravels or chalk are most productive; clay soils, which retain moisture and equalise the differential, are largely unresponsive.2 The critical advantage of multispectral imaging over conventional aerial photography is its ability to capture wavelengths beyond the visible spectrum. The near-infrared (NIR) band (approximately 700–1000 nm) is particularly sensitive to chlorophyll content and plant vigour: stressed crops reflect less NIR radiation than healthy ones. This means that cropmarks which are invisible or ambiguous in standard red-green-blue (RGB) photography can be clearly resolved in NIR imagery, often appearing earlier in the growing season and persisting longer. Historic England's satellite and multispectral imagery page notes that "by manipulating the different wavelengths it is possible to reveal features not otherwise easily discernible," and that NIR and other wavelengths recorded by multispectral sensors have "some potential for archaeological survey."3 Beyond multispectral data, hyperspectral imaging captures hundreds of narrow, contiguous spectral bands across a continuous range, allowing the sensor to produce a full spectrum for every pixel in a scene. Where a multispectral sensor might record five to thirteen discrete bands, a hyperspectral instrument such as the CASI-2 records 288 bands at 2.4 nm spectral intervals. This far greater spectral resolution allows much more subtle discrimination of vegetation stress patterns, though at considerably greater cost and complexity.

2.2 Equipment: Platforms and Sensors

The equipment used for multispectral archaeological survey in Britain falls into three broad categories: airborne hyperspectral scanners, satellite multispectral sensors, and drone-mounted multispectral cameras. Each occupies a different position in the trade-off between spatial resolution, spectral resolution, area coverage, and cost.

2.2.1 Airborne Hyperspectral Systems

The most powerful airborne hyperspectral instrument used in British archaeological research is the CASI (Compact Airborne Spectrographic Imager), manufactured by ITRES Research Ltd of Canada. The CASI-2, used in the landmark studies by Aqdus, Drummond, and Atkinson, captures 288 spectral bands across the 400–1050 nm range at 2.4 nm spectral resolution, with 512 spatial pixels across the swath. Flown at altitudes of 1,000–3,000 metres, it typically achieves a ground resolution of 1–2 metres for archaeological survey purposes. The instrument's ability to classify vegetation stress with exceptional spectral precision makes it the gold standard for cropmark detection, though the cost of aircraft operations and data processing places it firmly in the domain of funded research projects rather than volunteer fieldwork. An earlier generation of airborne multispectral scanner, the Daedalus ATM (Airborne Thematic Mapper), was used in pioneering British archaeological remote sensing. The ATM records eleven channels from the visible to the thermal infrared. Caldwell's 2000 study of cropmark detection in the Heslerton Parish Project area of the Vale of Pickering, North Yorkshire, used ATM data and demonstrated that "the appearance of crop marks on imagery varies considerably according to the stage of crop growth and the time of year" — an important finding for survey planning.4

2.2.2 Satellite Multispectral Systems

The principal satellite platforms relevant to Roman road research in Britain are as follows. WorldView-2 and WorldView-3 (Maxar Technologies) offer the highest spatial resolution commercially available: WorldView-2 provides eight multispectral bands (including coastal blue, yellow, red edge, and two NIR bands) at 2.0 m resolution alongside a 0.46 m panchromatic band; WorldView-3 extends this to sixteen multispectral bands at 1.24 m with a 0.31 m panchromatic channel. The inclusion of the red-edge band (approximately 705–745 nm) is particularly valuable for detecting subtle vegetation stress. Earlier platforms — IKONOS, QuickBird, and GeoEye — provided the first high-resolution satellite data used in archaeological research, with QuickBird's 2.4 m multispectral resolution used in early cropmark detection studies by Lasaponara and Masini.5 The Sentinel-2 constellation (European Space Agency Copernicus programme) offers thirteen spectral bands at 10–60 m resolution with a five-day revisit cycle, and is freely available. Zanni and Toscano's 2019 study in Geosciences used Sentinel-2 imagery to identify sixty cropmarks possibly related to buried archaeological remains.6 The temporal frequency of Sentinel-2 — its ability to image the same area repeatedly through the growing season — is a significant advantage for predicting optimal reconnaissance windows, even if its 10 m spatial resolution is too coarse to resolve individual road features with confidence. Historic England notes that in England, "limitations of cost and resolution coupled with poor weather conditions that limit the number of cloud-free scenes had meant that satellite imagery was rarely used," but that advances in resolution and the development of constellation systems are making this "an area that deserves further investigation."3

2.2.3 Drone-Mounted Multispectral Cameras

The most significant recent development in multispectral survey for Roman road research has been the proliferation of UAV (unmanned aerial vehicle) or drone-mounted multispectral cameras. These instruments combine the high spatial resolution achievable from low-altitude flight (typically 8 cm/pixel at 120 m altitude) with the spectral sensitivity of dedicated multispectral sensors, at a fraction of the cost of manned aircraft operations. The MicaSense RedEdge-MX and its successor the Altum are the instruments most widely used in British archaeological research. The RedEdge-MX weighs approximately 135 g and captures five spectral bands — blue, green, red, red edge, and NIR — with an integrated downwelling light sensor for radiometric calibration. The Parrot Sequoia offers a similar fourband configuration at lower cost. The DJI Phantom 4 Multispectral integrates a six-camera array (one RGB plus five multispectral) with a built-in sunlight sensor, making it accessible to non-specialist users. The landmark British study using drone multispectral survey for Roman road detection is Brooke and Clutterbuck's 2020 paper in Remote Sensing, "Mapping Heterogeneous Buried Archaeological Features Using Multisensor Data from Unmanned Aerial Vehicles."7 Surveying two sites in Nottinghamshire — Camp Hill (an Iron Age hillfort with a Roman road cutting through it) and Shelford Priory — the authors deployed a fixed-wing UAV carrying RGB, multispectral, and thermal sensors. Their key finding was that LiDAR had already revealed the Roman road at Camp Hill, but "the nature of the interior complex has remained elusive as the ground resolution of the LiDAR data is 1 m, and also as many archaeological features evidently do not present as significant topological variations due to extensive past agricultural activity." The multispectral data and derived NDVI (Normalised Difference Vegetation Index) revealed features that LiDAR had missed entirely. The authors' central methodological conclusion — that "no single technique is sufficient to attempt to reveal the maximum amount of potential information" — applies with equal force to the search for Roman roads across Britain.

2.3 Vegetation Indices

The raw spectral data from multispectral sensors is typically processed into vegetation indices — mathematical combinations of spectral bands designed to isolate and amplify the signal of plant stress. The most widely used is the NDVI (Normalised Difference Vegetation Index): (NIR – Red) / (NIR + Red). NDVI values range from –1 to +1, with healthy vegetation producing values above approximately 0.3 and stressed or absent vegetation producing lower values. A Roman road's compacted surface produces a band of low NDVI values; its flanking ditches produce a band of elevated values. More sensitive indices include the NDRE (Normalised Difference Red Edge), which substitutes the red-edge band for the red band and is more sensitive to subtle chlorophyll variations at early stages of stress; the GNDVI (Green NDVI), which uses the green band and responds differently to canopy structure; and the SAVI (Soil Adjusted Vegetation Index), which corrects for the influence of bare soil background on the NDVI signal. Oxford University researcher Morley's 2025 doctoral work at the University of Oxford used high-resolution drone multispectral data to "statistically validate and reprioritise the detection efficiency of several broadband vegetation indices" for subsurface anomaly detection in British landscapes — a significant methodological advance.8

2.4 What Multispectral Imaging Can Do for Roman Road Research

Multispectral imaging occupies a complementary niche to LiDAR in the British landscape. Where LiDAR excels in upland, wooded, and pastoral settings where the agger survives as a topographic feature, multispectral imaging excels in the lowland arable landscapes where centuries of ploughing have destroyed all surface expression. The technique can reveal the negative cropmark of a compacted road surface and the positive cropmarks of its flanking ditches, sometimes tracing a road for many kilometres across open farmland. In exceptional drought years — 1976, 1996, and 2018 are the most celebrated in British aerial archaeology — the combination of dry soils and stressed crops produces cropmark visibility of extraordinary extent and clarity, revealing features that may not reappear for decades. The RRRA's Itinera journal, published since 2021, explicitly welcomes "reports of excavations, new discoveries from lidar, aerial photography, and geophysics," recognising aerial multispectral survey as a core method alongside LiDAR.9 The Binchester (Vinovium) case study documented in the RRRA's Summer 2018 Newsletter illustrates the multi-method approach in practice: a road heading north-east from the fort was "already suggested by both geophysics and aerial photography," with LiDAR then extending the probable line further into the landscape.10 The technique also operates at multiple scales. Satellite multispectral data (particularly Sentinel2) can be used to identify optimal survey windows by monitoring crop development across entire counties, directing manned or drone survey to fields where stress patterns are developing. Highresolution drone surveys can then map individual road features at centimetre resolution, providing data suitable for detailed interpretation and publication.

2.5 What Multispectral Imaging Cannot Do

The limitations of multispectral imaging for Roman road research are substantial and in several respects mirror those of LiDAR, though in different landscape contexts. The technique requires arable crops. Multispectral imaging is entirely dependent on the presence of growing crops — typically cereals — to generate cropmarks. In permanent pasture, which covers much of upland Britain and many lowland areas, there is no seasonal crop stress differential and the technique produces no useful signal. Similarly, in woodland, the canopy completely obscures the ground surface. This means that multispectral imaging is largely confined to the lowland arable landscapes of eastern and southern England, precisely the areas where LiDAR is least effective due to ploughing — which is why the two techniques are so complementary. The technique requires dry conditions. The cropmark mechanism depends on soil moisture stress: in wet years, or on clay soils that retain moisture effectively, the differential between road surface and surrounding soil is equalised and cropmarks do not form. Historic England's guidance notes that "clay soils, which tend to be better at retaining moisture" are "less likely to produce cropmarks."2 Much of the English Midlands, parts of the Vale of York, and large areas of lowland Britain are underlain by clay, severely limiting the technique's applicability. Britain's characteristically wet and cloudy climate also restricts the number of cloud-free satellite acquisition windows, a constraint that Historic England has explicitly acknowledged.3 The technique is temporally unpredictable. Cropmarks appear at different times in different years, depending on the interaction of crop variety, soil type, subsoil geology, and seasonal rainfall. A road that produces vivid cropmarks in a drought year may be completely invisible in a normal year. This unpredictability requires sustained, multi-year monitoring programmes rather than single-season surveys — a significant resource commitment. The technique cannot authenticate Roman origin. A negative cropmark indicating a compacted linear feature could represent a Roman road, a medieval trackway, a post-medieval field boundary, a drainage pipe, or a geological feature. As Historic England warns, "pipelines, land drains, recently removed field boundaries — all can produce cropmarks, while agricultural practices such as irrigation and weedkilling techniques can also affect crop growth, often producing circular or linear variations in growth that can resemble the shapes and forms of particular types of archaeological monuments."2 The identification of a cropmark as a Roman road requires corroboration from other sources. The technique provides no depth information. Multispectral imaging is a surface observation technique: it records what is happening to crops at the surface and infers the presence of buried features from that signal. It cannot determine how deeply a road is buried, what its construction sequence is, or whether it survives as a coherent structure. These questions require geophysical survey or excavation. The technique is ineffective in urban areas. Modern urban development, with its impermeable surfaces and disturbed soils, completely prevents cropmark formation.

3. Ground-Penetrating Radar

3.1 The Physical Principle: Subsurface Electromagnetic Reflection

Ground-penetrating radar (GPR) operates on a fundamentally different physical principle from either LiDAR or multispectral imaging. Rather than detecting surface topography or crop stress, GPR investigates the subsurface directly by transmitting short pulses of electromagnetic energy into the ground and recording the reflections that return when those pulses encounter interfaces between materials with different dielectric properties — that is, different electrical permittivities. Stone differs from soil; gravel differs from clay; a void differs from fill; dry material differs from wet. Each such interface produces a characteristic reflection, the time delay of which indicates the depth of the feature. As Wessex Archaeology's GPR practice page explains, "GPR works by transmitting an electromagnetic pulse into the ground at regular intervals. These pulses then reflect off features in the ground and are detected by a receiver antenna. By measuring the strength and time delay of the responses it is possible to estimate the depth of the below ground features."11 Collecting data along a series of parallel transects across an area allows the construction of a threedimensional volumetric image of the subsurface — a capability that no other remote sensing technique can match. For Roman road research, GPR can detect several distinct elements of road structure. The metalled surface — the layer of compacted gravel, stone, or cobbles that formed the road's wearing course — produces a strong, continuous reflection at a consistent depth. Beneath it, foundation layers of larger stones or rammed earth may produce additional reflections. The characteristic cambered profile of the agger — slightly higher at the centre than the edges to shed rainwater — is visible in cross-section as a curved reflection. The flanking ditches, cut into the subsoil and subsequently filled, appear as U-shaped or V-shaped features in the radar profile. Where a road has been resurfaced or repaired, multiple overlapping reflections may indicate successive phases of construction.

3.2 Equipment: Systems and Antenna Frequencies

The choice of GPR equipment for Roman road research involves a fundamental trade-off: higher antenna frequencies produce finer spatial resolution but penetrate only shallowly into the ground, while lower frequencies penetrate more deeply but at the cost of resolution. This trade-off is not merely technical but archaeological: the depth at which a Roman road is buried varies enormously across Britain, from near-surface in upland areas to several metres below modern ground level in urban contexts where centuries of occupation have raised the ground surface. The following table summarises the principal frequency options and their archaeological applications: Antenna Frequency Typical Depth Penetration Approximate Resolution Principal Archaeological Use 50–100 MHz 10–20 m ~0.5 m Deep geological features; deeply buried urban deposits 200–250 MHz 3–5 m ~0.15–0.20 m Deeply buried Roman deposits in urban contexts 400–500 MHz 1–2 m ~0.05–0.10 m Standard archaeology; most rural Roman roads 1,000 MHz

0.5–1 m

~0.02–0.05 m Shallow, high-resolution features; near-surface road surfaces 2,000+ MHz

0.2–0.5 m

~0.01 m Very shallow, near-surface detail The Sensors & Software field guide for archaeologists notes that “the antenna frequency typically used for archaeology is 500 MHz because it provides high resolution and typically 1 to 2 meters of penetration” — appropriate for most rural Roman road surveys where the road surface lies within a metre or two of the modern ground.12

3.2.1 Single-Antenna Research Systems

The Sensors & Software pulseEKKO PRO is the instrument of choice for research-grade GPR in British archaeology. It is available with a range of shielded and unshielded antennas from 50 to 1,000 MHz, and its modular design allows different frequencies to be tested on the same site. The pulseEKKO PRO was the instrument used in the NERC-funded pilot study of Roman York conducted by Verdonck, Creighton, and Millett in August 2022, which is the most technically detailed GPR study of Roman road infrastructure in Britain published to date.13 That study, documented in NERC GEF Scientific Report 1148, provides an unusually candid account of the frequency selection process. The Roman deposits at York are buried at depths of

1.5 metres or more, beneath the foundations of medieval and post-medieval structures. Testing

a range of frequencies, the team found that a 500 MHz antenna produced “wave attenuation [that] prevented the detection of Roman structures,” while 100 MHz antennas provided insufficient lateral resolution to distinguish individual features. Frequencies between 200 and 300 MHz — specifically the shielded 250 MHz antenna — proved optimal, “allowing the identification of a barrack at a depth of 1.5–2 m, and of the foundations of the archbishop’s palace down to a depth of ~2.5 m.”13 The shielded antenna was preferred over unshielded alternatives because “above-ground objects surrounding the survey area complicated the interpretation of the data acquired with the unshielded antennas” — a practical consideration of great importance in urban environments. The GSSI SIR series (Geophysical Survey Systems Inc.) is the other dominant research platform in British archaeology. The SIR-3000, SIR-4000, and SIR-30 systems accept antennas from 200 to 2,600 MHz. Archaeological Surveys Ltd carries out the majority of its work using the UTSI Groundvue system with either 400 MHz or 250 MHz antennas — a configuration well suited to the range of depths at which Roman roads are typically encountered in rural Britain.14 The MALA RAMAC/CX (Swedish manufacture) is widely used across Europe and offers antennas from 25 to 1,600 MHz. The Sensors & Software Noggin SmartCart — a portable, self-contained system available with 250 or 500 MHz antennas — is particularly suited to rapid reconnaissance survey. It was the instrument used in a UK Roman road survey documented by Sensors & Software, in which a graphic demonstration of the impact of saline groundwater on GPR penetration was observed while searching for a Roman road near a coastal saltwater marsh.15

3.2.2 Multi-Channel Array Systems

For large-area survey — the kind of coverage needed to trace a Roman road across a landscape rather than merely characterise a known section — single-antenna systems are impractically slow. Multi-channel array systems mount multiple antennas on a single frame, covering a wider swath with each pass and dramatically increasing survey speed. Wessex Archaeology uses the MALA MIRA (Multi-channel Impulse Radar Array) system, which "comprises an array of several closely spaced antenna to provide a much more detailed survey than is practically possible than with a single antenna. The array can be vehicle towed to allow quicker coverage of large areas, making it a more practical prospection solution than single antenna survey as well as providing a much higher level of detail."11 The IDS GeoRadar Stream EM (now part of Hexagon) is a sixteen-channel vehicle-towed system capable of surveying at up to 40 km/h, increasingly used for archaeological landscape surveys as well as infrastructure inspection. These systems produce dense, three-dimensional data cubes that can be interrogated at any depth, providing a far richer picture of subsurface archaeology than single-profile survey. The most spectacular demonstration of what multi-channel GPR array survey can achieve for Roman archaeology is Verdonck et al.'s 2020 study at Falerii Novi in Lazio, Italy, published in Antiquity.16 Using a vehicle-towed multi-channel system to survey the entire 30.5-hectare area of a complete Roman town, the team produced a detailed subsurface map revealing the forum, temples, a macellum, an amphitheatre, a bath complex, and — crucially for road research — the complete street plan of the town, including road widths, kerb lines, and drainage channels. While Falerii Novi is an Italian site, the methodological demonstration of what GPR array survey can achieve for Roman urban infrastructure has directly informed British research programmes, most notably the "Roman York Beneath the Streets" project.

3.2.3 The RRRA Geophysics Programme

The Roman Roads Research Association has invested in its own geophysical survey capability, documented in its Summer 2018 Newsletter.10 The RRRA acquired a Sensys Magneto MXPDA 5-channel magnetometer — a German-manufactured fluxgate gradiometer array with integrated GPS, configurable with probe spacings of 25 cm (for higher resolution) or 50 cm (for wider coverage at 2.5 m per pass), and capable of being towed behind a vehicle for large-area survey. The instrument was trialled on the supposed line of RR29 (Petuaria to Malton) on the Londesborough Estate in the East Riding, where it revealed two clear linear features interpreted as probable ditches flanking a possible agger. The RRRA's geophysics programme uses magnetometry as its primary tool — faster and cheaper than GPR for large-area survey — with GPR deployed for targeted characterisation of specific anomalies. This distinction between magnetometry and GPR is important. Magnetometry (fluxgate gradiometry) detects variations in the magnetic susceptibility of soils — particularly the enhanced magnetism of ditch fills, hearths, and fired materials — and can cover four or more hectares per day with a multi-probe cart. It is excellent for detecting the ditches flanking a Roman road but less effective for detecting the road surface itself, particularly where the metalling rests on bedrock or geological gravel with similar magnetic properties. GPR, by contrast, detects dielectric contrasts and is well suited to detecting stone-on-stone features, road surfaces, and the depth profile of buried structures, but covers ground more slowly and is more sensitive to soil conditions. The two techniques are genuinely complementary, and the most productive geophysical surveys of Roman roads in Britain use both.

3.3 British Case Studies

3.3.1 Roman York: Beneath the Streets

The most ambitious GPR programme focused on Roman road infrastructure in Britain is the AHRC-funded “Roman York Beneath the Streets” project, directed by Professor Martin Millett (University of Cambridge) and Dr John Creighton (University of Reading), with GPR survey led by Dr Lieven Verdonck (Ghent University). The project has produced three published GPR reports deposited in the Cambridge University Repository, covering the York Minster precinct, St Mary’s Abbey, and the streets of the city centre.17 The city centre streets survey (Report 3, 2025) is particularly instructive as a case study in GPR’s limitations. A step-frequency GPR system was dragged along five hectares of York city centre streets, operating across a frequency range of 200–3,000 MHz to capture data from the surface to a depth of three metres or more. The survey registered details of road makeup, services, and utilities with clarity. However, “unfortunately, no identifiably Roman features were discovered. The problem was not caused by utilities, but significant signal attenuation, with few features visible below about one meter. No archaeology was observed below this depth, even when the survey was above known archaeological features.”17 Resurveying with the 250 MHz antenna that had performed well on open grass areas within the city made no difference. The team concluded that the attenuation was caused by “the road makeup, and beneath that the attenuation from clay and sedimentary deposits” — a stark demonstration that GPR’s effectiveness is fundamentally controlled by soil conditions, and that even the most sophisticated equipment cannot overcome the physics of signal absorption in conductive materials. The open-area surveys within the city (Reports 1 and 2), conducted on grass-covered ground in Dean’s Park and the Yorkshire Museum gardens, produced far better results. The 250 MHz shielded antenna successfully identified Roman barracks, streets, and structural remains at depths of 1.5–2.5 metres — the same instrument that failed on the city streets. The contrast between these results and those from the streets survey illustrates the critical importance of ground conditions.

3.3.2 Silchester (Calleva Atrebatum)

Neil Linford’s 2004 paper in Archaeological Prospection, “From Hypocaust to Hyperbola: Ground-Penetrating Radar Surveys over Mainly Roman Remains in the UK,” remains a foundational reference for GPR survey of Roman sites in Britain.18 The paper documents GPR surveys at several Roman sites, most notably Silchester in Hampshire — one of the bestpreserved Roman towns in Britain, where the street grid survives largely unencumbered by later development. The survey demonstrated that “the Roman street plan is clearly shown as a regular network” in the

GPR data, with road surfaces, flanking features, and associated structures all clearly resolved. Linford's subsequent work at Silchester, culminating in the Silchester Mapping Project (2005–10), used stepped-frequency GPR with a multi-element array to produce a comprehensive subsurface map of the town, documenting the internal street plan in detail.19

3.3.3 Binchester (Vinovium) and Dere Street

The RRRA's Summer 2018 Newsletter documents the use of geophysical survey at Binchester fort in County Durham, where Dere Street (RR8) forms the via principalis of the fort and "can be clearly seen on the geophysics."10 The composite plot of geophysical surveys at Vinovium from 2009 and earlier work shows the road as a clear linear feature crossing the fort interior. This case illustrates the value of geophysics for confirming road alignments at known Roman sites, and for investigating the question of whether bypass roads skirted around forts — a question that the Binchester surveys have so far failed to resolve, finding no evidence of such a bypass despite extensive survey. The Britannia annual reports provide a running record of GPR and geophysical survey work on Roman roads across Britain. The 2016 report documents GPR results at a site on the line of the road from Ambleside, where a feature "is typical of a Roman road agger"; the 2013 report records "further Ground Penetrating Radar survey work" on a road where a raised agger had been first detected in 2012; and the 2018 report documents GPR and resistivity survey on the projected line of the Roman road connecting Carmarthen.20 These brief notices, scattered across successive volumes of Britannia, collectively represent a substantial body of GPR work on Roman roads in Britain, much of it conducted by commercial archaeological contractors as part of planning-led investigations.

3.4 What GPR Can Do for Roman Road Research

GPR's most important contribution to Roman road research is its ability to detect road structure below the surface, in contexts where no other non-invasive technique can provide reliable information. In urban areas, where LiDAR is defeated by modern development and multispectral imaging cannot function, GPR is often the only viable non-invasive method. It can detect road metalling, foundation layers, and flanking ditches at depths of one to three metres or more, depending on soil conditions and antenna frequency. It provides depth information — a dimension entirely absent from LiDAR and multispectral imaging — allowing researchers to understand how deeply a road is buried and what its relationship is to overlying deposits. GPR can also detect multiple phases of road construction: a Roman road that was resurfaced several times, or that was later overlain by a medieval or post-medieval surface, may show as a stack of reflections at different depths, each representing a distinct construction episode. This stratigraphic information is of great historical value and cannot be obtained from surface survey methods. The technique works in all weather conditions and at any time of year, unlike multispectral imaging, which is dependent on crop growth and dry conditions. It can operate on hard surfaces — roads, car parks, pavements — making it uniquely suited to urban investigations. It can also be used inside buildings, a capability that has been exploited to investigate Roman structures beneath medieval and modern buildings in York and elsewhere.

3.5 What GPR Cannot Do

GPR's limitations are as significant as its capabilities, and understanding them is essential for designing effective survey programmes. Clay soils are the fundamental constraint. Clay minerals have high electrical conductivity, which causes rapid attenuation of the GPR signal. In clay-rich soils, the signal may be absorbed within the top 0.5 metres of the ground, making it impossible to detect features at archaeological depths. This is a severe limitation in Britain, where clay soils underlie much of the Midlands, parts of the Vale of York, and large areas of lowland England — precisely the regions where Roman roads are most densely distributed. The York city centre streets survey, where clay and sedimentary deposits caused "significant signal attenuation, with few features visible below about one meter," is a vivid illustration of this constraint.17 Saline groundwater is equally problematic. Salt water is highly electrically conductive and completely blocks the GPR signal. The Sensors & Software case study of a Roman road survey near a coastal saltwater marsh in the UK demonstrated this dramatically: as the survey crossed onto a sand spit near a saltwater marsh, GPR penetration dropped abruptly to near zero due to saline groundwater intrusion.15 Coastal sites and areas with saline groundwater are effectively inaccessible to GPR. Waterlogged ground presents similar problems: saturated soils attenuate the signal, though less severely than saline water. This is a significant constraint in the Fens, river floodplains, and other low-lying areas where Roman roads are known to cross. Large-area survey is slow and expensive. Even with multi-channel array systems, GPR survey is considerably slower and more expensive than magnetometry. A single-antenna system might cover 0.5–1 hectare per day; a vehicle-towed array might cover 5–10 hectares per day. Tracing a Roman road for tens of kilometres across a landscape using GPR alone is not practically feasible; the technique is best deployed for targeted investigation of specific anomalies identified by faster methods. GPR cannot authenticate Roman origin. Like LiDAR and multispectral imaging, GPR can detect a buried linear feature with the structural characteristics of a road — compacted material, flanking ditches, cambered profile — but it cannot determine whether that road is Roman, medieval, or post-medieval. Dating requires excavation and the recovery of datable artefacts or organic material. Features without dielectric contrast are invisible. If a road surface has the same dielectric properties as the surrounding soil — for example, if a lightly constructed road of compacted earth has been thoroughly mixed with the surrounding matrix by ploughing or bioturbation — it will produce no reflection and will be invisible to GPR. This is a particular concern for minor local roads and tracks that lacked substantial stone metalling.

4. The Silver Bullet Question

4.1 Multispectral Imaging: Transformative but Conditional

Multispectral imaging is not a silver bullet for Roman road research, but it is a genuinely transformative tool in specific contexts. Its great strength is its ability to detect Roman roads in lowland arable landscapes where LiDAR fails — the very landscapes where the Roman road network was densest and where the greatest gaps in our knowledge remain. In exceptional drought years, satellite and aerial multispectral survey can reveal road alignments across entire regions in a single season, providing a landscape-scale perspective that no ground-based method can match. However, the technique's dependence on crops, dry weather, and well-drained soils means that it is effective over only a fraction of the British landscape in any given year. It provides no depth information, cannot authenticate Roman origin, and requires sustained multi-year monitoring to build a reliable picture. The Brooke and Clutterbuck finding — that “no single technique is sufficient” — applies with particular force to multispectral imaging, which is most powerful when combined with LiDAR (for upland and wooded areas), GPR (for subsurface confirmation), and magnetometry (for rapid large-area survey).

4.2 GPR: Indispensable in Specific Contexts, Limited Elsewhere

GPR is not a silver bullet either, but it fills a niche that no other technique occupies: the direct, non-invasive investigation of subsurface road structure in urban contexts and in areas where surface expression has been entirely destroyed. The “Roman York Beneath the Streets” project has demonstrated both the potential and the limitations of GPR in urban Roman archaeology with unusual candour: the technique succeeded brilliantly on open grass areas but failed completely on the city streets, defeated by clay and sedimentary deposits. This contrast encapsulates GPR’s fundamental character — a technique of great power in the right conditions, but highly sensitive to the geological and pedological context. For rural Roman road research, GPR is most valuable as a targeted tool: deployed to characterise a specific anomaly identified by LiDAR or multispectral survey, to determine the depth and structural character of a suspected road, or to investigate a section of road in advance of excavation. The RRRA’s approach — using magnetometry for rapid large-area survey and GPR for targeted characterisation — represents best practice.

4.3 The Multi-Method Imperative

The consistent message from both the practitioner community represented by twithr.co.uk and romanroads.org, and the academic research literature, is that Roman road research requires a multi-method approach in which no single technique is privileged over others. The most productive investigations combine: LiDAR for upland, wooded, and pastoral landscapes, revealing the agger and flanking ditches as topographic features; Multispectral imaging (aerial, satellite, and drone) for lowland arable landscapes, revealing cropmarks in dry summers; Magnetometry for rapid large-area geophysical survey, detecting ditch fills and associated features; GPR for targeted subsurface characterisation, urban investigation, and depth profiling; Historical mapping and documentary research for establishing baseline alignments and identifying gaps; Excavation as the ultimate arbiter of Roman date and structural character. The RRRA’s Itinera journal, with its explicit commitment to publishing “reports of excavations, new discoveries from lidar, aerial photography, and geophysics,” embodies this multi-method philosophy.9 The Binchester case — where geophysics confirmed Dere Street’s alignment through the fort, aerial photography suggested a road heading north-east, and LiDAR extended the probable line further into the landscape — illustrates how each technique contributes a different piece of the puzzle.10

5. Conclusion

Multispectral imaging and ground-penetrating radar are powerful and genuinely complementary tools for Roman road research in Britain, each capable of revealing features that the other cannot detect. Multispectral imaging transforms the investigation of lowland arable landscapes, detecting the cropmark signatures of compacted road surfaces and flanking ditches in conditions where LiDAR is blind. GPR transforms the investigation of urban contexts and subsurface structure, providing depth profiles and three-dimensional images of buried road construction that no surface method can supply. Neither technique is a silver bullet. Multispectral imaging requires crops, dry weather, and welldrained soils; it provides no depth information and cannot authenticate Roman origin. GPR is defeated by clay soils, saline groundwater, and waterlogged conditions; it is slow and expensive for large-area survey; and it too cannot date what it detects. Both techniques are most powerful when combined with LiDAR, magnetometry, historical research, and — ultimately — targeted excavation. The Roman road network of Britain remains incompletely mapped after more than a century of systematic research. The combination of freely available LiDAR data, increasingly accessible drone multispectral sensors, and research-grade GPR equipment means that the tools now exist to make substantial progress. The challenge is not technological but methodological: deploying the right technique in the right landscape context, interpreting results with appropriate caution, and always remembering that the identification of a linear feature as a Roman road requires not merely detection but authentication. References and Further Reading This report is a companion piece to LiDAR and the Roman Roads of Britain (2025), and should be read alongside it. Together, the two reports assess the full range of remote sensing and geophysical techniques currently available for Roman road research in the British landscape.

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