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Caesium vapour magnetic survey - FAQ

Q1. Do see caesium magnetometers "see" deeper than fluxgates?

A. There is no such quantity as the depth to which a magnetometer will detect features. It depends entirely upon the interrelationship between many variables including the susceptibility contrast between a feature and its surroundings and the susceptibility and thickness of the materials covering it. It also depends upon the measurement resolution of the instrument and the physical arrangement of the sensors. The greater sensitivity of a caesium instrument than a fluxgate could, in particular situations, allow detection of features at greater depth than normally sought using a fluxgate.

Q2. Are caesium magnetometers more sensitive than fluxgate instruments?

A. Yes but some of the claims made by the archaeological community should be viewed with suspicion. The issue is not just sensitivity but amplitude resolution as that governs the smallest size of anomaly that can be reliably detected. The table below lists the resolutions that are reliably possible within the scope of normal archaeological survey:

Technology	Typical Instrument	Resolution (P-P)
Fluxgate (all makes)	Bartington 601	0.1nT
Terrestrial caesium at 10Hz (0.15m samples)	Geometrics 823B / MagMapper	0.03nT
Terrestrial caesium at 5Hz (0.30m samples)	Geometrics 823B / MagMapper	0.01nT
Aeronautic caesium at 10Hz (0.15m samples)	Geometrics 822 (+ supercounter)	0.002nT

Q3. Can caesium magnetometers detect more than fluxgate instruments?

A. Yes, in certain circumstances and through two separate mechanisms. The greater sensitivity or resolution allows weak anomalies to be measured with more confidence. A caesium gradiometer for example measuring a weak anomaly of 1nT is still operating two orders of magnitude greater than its maximum resolution (0.03nT). A fluxgate instrument, however, would at best be operating at only one order of magnitude greater than its resolution (0.1nT) and some surveyors have been known to use Geoscan Research FM36 instruments on a setting providing only 1nT resolution though this is hopefully rare!

The second mechanism relates to the instrument configuration. Fluxgate instruments can only function as gradiometers, not magnetometers and cannot therefore resolve broad lateral variations in magnetic intensity. The deeper a magnetic source is buried, the broader and less clear-cut the magnetic anomaly measured at the surface. For some features, e.g., those blanketed by alluvium, the horizontal variation of the anomaly is too subtle to be detected by short vertical gradiometers, as there is insufficient variation between the two sensors to permit reliable measurement. The greater resolution of a caesium gradiometer means it is better placed to detect this subtle variation. Also, the sensors can be spaced further apart to maximise the numerical difference between them.

In addition, the fact that caesium instruments do not have to be used as gradiometers means that the total magnetic intensity is usually measured and horizontal variations in the magnetic field are easily detected down to the 0.03nT at 10Hz limit.

Q4. Why do I need the sensitivity?

A. There are instances where archaeological features exhibit poor magnetic contrast with their surroundings and therefore exhibit weak magnetic anomalies at ground level. Sometimes this is because the soil cannot support strong enhancement from cultural activity, e.g., it is low in available iron. At other times, the cultural activity may not have resulted in strong magnetic variations, e.g., non-settlement sites with postholes. In addition, there are scenarios where features may be deeply buried or blanketed beneath magnetic soils.

All of these require an instrument capable of responding to changes in surface magnetic intensity that are very close to the minimum detectable using a fluxgate gradiometer. They may also require sensitivity to weak or diffuse lateral changes in magnetism that instruments configured as vertical gradiometers are poor at detecting.

The greater sensitivity of caesium magnetometers has proved useful in assessing changes in the magnetic texture of the ground, i.e., variations in what would be regarded as background to a gradiometer survey. These indicate changes in soil properties etc, can reflect past divisions in land use and are often manifest as anomalies smaller than 0.5nT and spatially tiny, essentially beyond reliable detection using a fluxgate gradiometer.

Q5. I've heard people say that caesium magnetometers produce noisier data – why?

A. This is a myth that was spread in ignorance of the true situation when the technology was first noticed by some archaeological surveyors as a common error was made which was to carry the instrument with the sensors close to the body, as is normal for fluxgate survey. However, in doing so they were carried too close to the logging console and consequently suffered electronic interference. The problem was not understood at the time by some surveyors. In addition, the instrument was sometimes configured as a short gradiometer and carried with the lower sensor close to the ground, which is not an optimum configuration for caesium technology.

Q6. I've heard that caesium magnetometers are pointless over the UK's noisy soils – is this correct?

A. This is due to a misconception of the purpose of using caesium technology and also due to comparing the normal silt and clay-rich soils of the UK with the predominant light loess of the continent. Loess is capable of supporting a reasonable susceptibility enhancement but its homogenous nature and great thickness mean that magnetic data collected over it has a uniform background, against which archaeological features are often clearly visible. Some continental surveyors have implied something different and suggested that caesium magnetometers were necessary to permit the detection of features in loess. However, the size of the anomalies they are detecting matches those from similar features in the UK and unfortunately it has led some people to imply that the lack of loess in the UK means the greater sensitivity is unnecessary.

The more varied nature of UK soil means that there are natural magnetic variations present that can be locally rather strong but this rarely affects the visibility of archaeological features unless the magnetometer is carried too low over freshly turned soil. The noise that results is due to the transport of relatively non-magnetic subsoil to the surface, mixed in with any magnetic cultural debris from below the ploughsoil. However, soil that has not been freshly turned can appear as magnetically quiet as loess and anomalies at the limit of detection by fluxgate gradiometers can be clearly apparent to caesium magnetometers.

Q7. Fluxgate instruments are apparently better able to resolve closely spaced features better than caesium magnetometers – is this correct?

A. Not really. The vertical magnetic gradiometer produces the strongest response to strong lateral changes in magnetic field strength at the lower sensor and not broad subtle ones. This is due to the nature of a gradiometric measurement and applies to all instruments using this configuration. Most caesium instruments are not configured as gradiometers and are theoretically less able to resolve closely spaced features as a consequence but this has not proved an issue for normal archaeological features. In addition, there are properties particular to the total field measurement of caesium magnetometers that allow the vertical gradient to be readily synthesised so it reflects the performance of a gradiometer.

Q8. Do caesium magnetometers have to work in regular grids?

A. No, data is measured as a stream sampled evenly in time along each line and lines can be different lengths. A nominal grid can contain any number of lines and it is possible to survey any arbitrary shaped area. Data is usually collected as large panels to avoid the errors commonly introduced when merging many small grids together.

Q9. I've heard that caesium instruments are more prone to break down than other instruments – is this true?

A. No. When the technology first emerged there were teething problems as there have been for all instruments but these were resolved years ago and modern instruments are robust. The instruments are sensitive to tiny changes in magnetic fields so they need to be used with perhaps greater care than a fluxgate instrument for example.

Q10. Are caesium magnetometers more expensive than fluxgate instruments?

A. Yes, significantly more so and this reflects the greater degree of engineering and testing that goes into their construction. They also tend to have much more advanced logging and console functions than most fluxgate instruments permitting greater flexibility of use.

Q11. Do caesium surveys cost more?

A. Surveys by ArchaeoPhysica using caesium magnetometers cost a similar amount to surveys using fluxgate magnetometers by other surveyors, after all, we have been competing in the UK market for many years!

Q12. Are the results comparable with fluxgate surveys?

A. There is a difference in what people perceive as the result but overall they are completely comparable. Data can be presented in the same way and interpreted the same way when it comes to producing plans of potential features. The physical nature of the data is somewhat different, due partly to the lower noise levels, the often higher along-line resolution and perhaps most importantly, the total field character. Anomalies tend to be slightly stronger and raw total magnetic intensity data includes variations from near surface rock and soil as well as archaeological features. Sometimes this can considerably augment the interpretation, e.g., indicate where rock is close to the surface or where soil depth is varying significantly, but at other times this is less useful and these components can be easily suppressed by appropriate processing.

Q13. Can cart-mounted magnetometers cope with ground conditions?

A. It depends upon the cart! In general, most carts are built to permit survey in conditions that a carried instrument might be expected to cope with, e.g., slightly rough ground, medium length vegetation, etc. Where their use tends to be problematic is over freshly ploughed soil as wheels are obviously not suited to traversing this sort of terrain. However, the data from any carried instrument will be substantially degraded in these situations and an honest surveyor will admit that it is debatable whether it was worth collecting. In general, assume that if the ground can be sensibly and safely walked a cart-mounted instrument will be able to proceed, even on steep slopes.

The ArchaeoPhysica carts are built to present very little pressure on the ground from their wheels, permitting use on stripped surfaces, bare soil and sand. They disturb the ground no more than the surveyor's feet in these conditions.

Q14. Does the use of carts preclude survey into field corners or small sites?

A. No. Careful survey and cart design will allow all areas that require survey to be accessed and data to be collected. In any case many fields have one or more strands of wire incorporated within their boundaries and for each strand of wire about a metre of adjacent ground will exhibit strongly distorted magnetic fields. It is often pointless to pursue survey into these regions, whatever the magnetic technology in use.

Q15. What other benefits can caesium magnetometers offer?

A. An important benefit is the ability of caesium technology to produce quality management data for each survey. Data from each sensor can be logged for arbitrary lengths of time at a constant rate while stationary, allowing the performance of each to be separately assessed using statistical and frequency-based techniques. This means that the actual measurement resolution is known and not presumed and that temporal trends in performance can be measured and analysed. Somewhat unbelievably, ArchaeoPhysica is still the only UK surveyor to create and record these data quality measurements and inclusion for their provision in some recent third party specifications actually drew complaints from some surveyors!