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Halcrow

Cell 1 Regional Coastal Monitoring Programme
2012/13 Aerial Survey
Archaeological Assessment

Final Report

January 2014

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Preamble

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the north east coastline, from the Scottish Border (just south of St. Abb's Head) to Flamborough Head in East Yorkshire. This coastline is often referred to as 'Coastal Sediment Cell 1' in England and Wales (Figure 1). Within this frontage the coastal landforms vary considerably, comprising low-lying tidal flats with fringing salt marshes, hard rock cliffs that are mantled with glacial sediment to varying thicknesses, softer rock cliffs and extensive landslide complexes.

Figure 1 Sediment Cells in England and Wales

The work commenced with a three-year monitoring programme in September 2008 that was managed by Scarborough Borough Council on behalf of the North East Coastal Group. This initial phase has been followed by a five-year programme of work, which started in October 2011. The work is funded by the Environment Agency, working in partnership with the following organisations:

Northumberland County Council
Northumberland Coast 50 Years
North Tyneside Council
South Tyneside Council
Sunderland City Council
Durham County Council
Redcar & Cleveland Borough Council
Hartlepool Borough Council
Whitby Scarborough Filey Borough of Scarborough
A great place to live, work & play
East Riding of Yorkshire Council
Environment Agency
Natural England
The National Trust

1. Introduction and Data Used

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the northeast coastline from the Scottish Border to the southern boundary of Scarborough Borough Council, approximately 10km northwest of Flamborough Head. This report forms a component of the Cell 1 coastal monitoring programme analytical services being undertaken by Halcrow (rebranded as CH2M HILL since 2013) for a consortium of local authorities coordinated by Scarborough Borough Council.

The coastline of Cell 1 has been the subject of a number of archaeological assessments designed to support shoreline management plans (SMP). Previous surveys were part of the English Heritage Rapid Coastal Zone Assessment (RCZA) that informed the SMPs for the north-east coastline. These concentrated on systematic mapping of existing paper aerial photographs, desk reviews of designated data and undertaking condition surveys by means of walkover visits in order to assess the risk to archaeology of coastal erosion and sea-level rise (Table 1.1). None of these past studies have looked at the potential application of LiDAR and CASI data for archaeological survey.

The present archaeological assessment is therefore additional to these existing walkover and aerial photography interpretations. The purpose is to undertake a qualitative assessment of the application of the second Cell 1-wide aerial survey data of autumn 2012 to spring 2013 to the study of archaeology. The specific objectives of the work are to:

- To systematically review all the remote sensing data to highlight the presence of possible archaeological features
- Test the usefulness of the different remote sensing data for mapping archaeology by reviewing each dataset against English Heritage's GIS-based archaeology database of scheduled monuments

Until the cell-wide monitoring programme was developed, coastal monitoring was the responsibility of different coastal groups, resulting in surveys being uncoordinated and data being stored in different formats. The first consistent baseline aerial photography and LiDAR survey for the whole Cell 1 coastline was flown in 2010. This survey was repeated in 2012/13 to provide a second dataset that covers the whole of Cell 1. These surveys included synchronous collection of LiDAR height data, meaning digital elevation models (DEMs) and derived hillshade and slope models were available to supplement interpretation of the aerial photography (Table 1.2).

Table 1.2. Details of vertical aerial imagery currently available

Date	Data / Format	Resolution	Accuracy (RMSE)
Sept-Oct 2012 and April-May 2013	Orthorectified images (.ECW)	0.1 m	<0.1m
As above	LiDAR (.ASC)	1 m	<0.1m
As above	CASI (.IMG)	1 m	<0.1m

The principal objective of the 2010 and 2012/13 surveys was assessment of coastal change, but a CASI multispectral sensor was also deployed in the most recent survey to collect data for habitat mapping and archaeological assessment. The current assessment uses the 2012/13 data only. CASI (Compact Airborne Spectrographic Imager) is a device for recording light in the visible and near infrared parts of the spectrum. CASI is routinely used for environmental monitoring, particularly in relation to pollution of water, but has recently been used for archaeological investigations.

Table 1.1. Details of past archaeological assessments along Cell 1

Report	Date	Extent	Notes
Archaeological Research Services for English Heritage. North East Rapid Coastal Zone Assessment Survey	1 August 2008	Whitby to Scottish Border. LAT to 1km inland of MHSW.	Mapping from all available vertical and oblique aerial photography from 1940 to 2006 held by local authorities, National Monuments Records Centre and Cambridge University Collection of Air Photographs. LiDAR was available, but was not used as the data were captured at high tide.
Archaeological Research Services for English Heritage. North East Rapid Coastal Zone Assessment: Final Report.	31 Dec 2008	Whitby to Scottish Border. LAT to 1km inland of MHSW.	Desk study into threat posed by coastal erosion and sea-level rise to support SMPs. Data reviewed comprised historical environment records (HERs) maintained by local authorities and aerial photography that was mapped as part of English Heritage's National Mapping Programme
Archaeological Research Services for English Heritage. North East Rapid Coastal Zone Assessment: Phase 2.	31 May 2010	Whitby to Scottish Border. LAT to 1km inland of MHSW.	Field survey of 15 areas at risk from coastal erosion. Results feed into future SMPs
Humber Field Archaeology for English Heritage. Rapid Coastal Zone Assessment Survey Yorkshire and Lincolnshire: Whitby to Reighton	2 June 2008	Reighton to Whitby. LAT to 1km inland of MHSW.	Desk and field study into threat posed by coastal erosion and sea-level rise to support SMPs. Data reviewed comprised historical environment records (HERs) maintained by local authorities and results of English Heritage's National Mapping Programme. A limited walk-over of certain sites at risk was also undertaken.
Humber Field Archaeology for English Heritage. Rapid Coastal Zone Assessment Survey Yorkshire and Lincolnshire: Whitby to Reighton. Phase 2.	31 Jan 2011	Reighton to Whitby. LAT to 1km inland of MHSW.	Field-based condition assessment of known features identified in the 2 June 2008 report. Recommendations for trial trenching, geophysical and LiDAR surveys were made, but this work was not undertaken.
Humber Field Archaeology for English Heritage. Rapid Coastal Zone Assessment Survey Yorkshire and Lincolnshire: Bempton to Donna Nook	28 Feb 2008	Flamborough to Reighton. LAT to 1km inland of MHSW.	Desk and field study into threat posed by coastal erosion and sea-level rise to support SMPs. Data reviewed comprised historical environment records (HERs) maintained by local authorities and results of English Heritage's National Mapping Programme. A limited walk-over of certain sites at risk was also undertaken.
Humber Field Archaeology for English Heritage. Rapid Coastal Zone Assessment Survey Yorkshire and Lincolnshire: Bempton to Donna Nook. Phase 2.	31 Jan 2011	Flamborough to Reighton. LAT to 1km inland of MHSW.	Field-based condition assessment of known features identified in the 2 June 2008 report. Recommendations for trial trenching, geophysical and LiDAR surveys were made, but this work was not undertaken.

2. Recognising Archaeological Features in Remote Sensing Data

The following section sets out the type of archaeological features that this study has attempted to identify, and the background to archaeological reconnaissance mapping.

Archaeological sites mapped from aerial imagery have often been levelled by ploughing and are identified in photos as crop marks or soil marks that can have their archaeological significance inferred. These features are typically mapped from aerial photographs, with imagery captured in periods of drought or fresh vegetation growth being particularly useful. CASI data has the potential to differentiate the health of vegetation and can be useful in recognising buried archaeological features. LiDAR is very unlikely to identify buried features that have no surface expression.

Archaeological sites that have not been ploughed generally survive as low earthworks or slight stony banks that can be mapped and interpreted directly from imagery of the land surface or elevation data. These visible features can often be clearly seen in aerial photos, particularly if long shadows are present, but are more evident in LiDAR data that can be processed to highlight subtle patterns in elevation change.

2.1 Crop marks

Crop marks are patterns in vegetation reflecting differences in the rate of growth of a crop which are caused by variations in the moisture and nutrient content of the soil. These variations are caused by differences in the structure and profile of the subsoil that can be attributed to the presence of buried features. For example natural fissures or man-made ditches in the underlying bedrock or subsoil are usually filled with deeper, richer soils that will retain more moisture leading to localised areas of more vigorous growth.

The opposite is true for buried walls or compacted surfaces that retain less moisture than the surrounding field leading to localised areas of stunted growth, which is particularly marked in drought conditions.

Many types of crop develop crop marks, although the best are found in cereals, especially wheat and barley. Crop marks can be formed in all stages of a crop's growth cycle but the optimum time is from May to July when the crops are starting to ripen and the ground is often drier. Crop marks are usually visible as differences in vegetation colour, although differences in crop height can sometimes be observed.

2.2 Soil marks

During ploughing, in the months between autumn and spring, differences may be seen in the colour of freshly exposed bare soils as lighter coloured sub-soils are brought to the surface. When buried archaeological features are ploughed they often lead to observed differences in the colour of the soil across the field. This colour change may relate to ditches that will have filled with organic matter giving them a darker hue, or material forming banks or mounds that has been quarried from bedrock that will tend to be paler than the surrounding topsoil.

2.3 Earthworks and stoneworks

Earthwork sites are those where standing archaeological remains in the form of ditches, earth banks or low walls survive. Such features are readily recognised in aerial imagery and LiDAR

3 Methodology

All mapping and data interpretation was undertaken using a GIS database that included Ordnance Survey map tiles, the 2012/13 aerial photography, CASI and LiDAR and scheduled ancient monument data downloaded from the English Heritage website.

Scheduled Monument data was deliberately turned off in the initial phase of mapping to avoid interpretation being skewed towards known concentrations of archaeology. However, this data was used to comparing the visibility of known archaeological features in the different remote sensing datasets and to ensure that the mapped features were previously unknown.

Initially, the aerial photography data were systematically reviewed at a scale of 1:5,000 to observe key landmarks and to locate the main urban concentrations and locations of existing schedule ancient monuments. It was considered unlikely that new archaeological features would be identified within urbanised areas where contemporary buildings and infrastructure would disguise any buried archaeology. The work was therefore focused on the rural areas, which make up the majority of the study area.

Crop marks were initially targeted in arable or exposed areas. The vast majority could be identified as 'natural' (natural geological features) or resulting from modern activity such as pipelines and ploughing practices. Care was taken to view each potential archaeological feature in the context of the surrounding area to justify its inclusion.

Once these features had been mapped, the LiDAR and CASI data were also systematically examined at a scale of 1:2,500. Features that appeared unusual or anomalous within the prevailing topographic variations in the area were examined at a larger scale to confirm their significance before digitising.

All features interpreted as having archaeological potential were digitised as polygons. A short description was included for each feature and check boxes were used to which dataset(s) recorded the feature (photograph, CASI LIDAR). The majority of features were seen as crop marks or patterning of the ground in arable areas. Activities such as irregular ploughing, modern and historical services and also natural topographic variations sometimes appear as archaeological features.

4 Results

4.1 Features Identified

A total of 32 features or groups of features were identified during the exercise throughout the study area that are not included in the existing scheduled ancient monument dataset. The features mapped are summarised in Table 4.1. Full GIS data is provided on the accompanying disc (Appendix A).

The table highlights that LiDAR and aerial photography were the most useful datasets for archaeological mapping. Most features were visible in two or more of the datasets, but seven features were only visible in the LiDAR and nine were only visible in the aerial photograph. While only six features were recognised in the CASI data, two of them were not visible in the other datasets, indicating there is value in collection and interpretation of CASI data. Examples showing how the features are indicated in the various remote sensing datasets are provided in Figures 4.1, 4.2 and 4.3.

High resolution aerial photography offers the best means of rapidly scanning the landscape to identify potential archaeological features. LiDAR data offers more detail and provides a means of validating initial aerial reconnaissance results. However, it is important to note than where known archaeological features were present, LiDAR did not give any indication of presence of buried features. Overall, this work has demonstrated that an integrated review of all three remote sensing datasets provides the best method for assessment of archaeology.

The benefits of the integrated assessment were particularly evident in the case of the potential prehistoric round barrows, identified within an existing barrow field (features 30 and 31). The existing barrows are Scheduled Monuments and are very difficult to see in the LiDAR and CASI data. However they do faintly show as circular crop marks in the aerial photographs, which raises the possibility that further features could exist in this area. This in

turn suggests that a detailed programme of reconnaissance, perhaps involving ground surveys, would be an appropriate consideration in the event of long standing coastal erosion issues threatening such areas.

Whilst the majority of the features were crop marks and likely to represent prehistoric or perhaps Romano-British buried features, there were a number of linear features across the landscape which may relate to existing known archaeological features or buildings that are not Schedule Monuments and which consequently are not included in the English Nature GIS data used in this study.

Examples of such features include medieval dykes (feature 29) and possible post-Roman building platforms. In addition there were some potential anomalies in the form of linear features that are likely to represent former railways or buried infrastructure (features 10 and 21).

4.2 Recommendations for Further Work

This work has reviewed LiDAR, aerial imagery and CASI data captured in 2012/13 in order to map potential archaeological features. The mapping has been compared with existing data on Scheduled Monuments to identify those features that are not potentially new discoveries. Before the mapped features can be confirmed as new discoveries, they require validation against existing data on Historic Environment Records, such as that documented in the RCZAs listed in Table 1.1. These data are generally not available on-line and are held by county councils or English Heritage.

The Shoreline Management Plan (SMP2) and associated Phase 2 RCZAs and for the NE coast have established a baseline for the historic environment in the immediate coastal area from MLW to 1km inland of MHWS. Although the majority of the identified features are under no imminent threat of erosion, it is recommended that on-going monitoring is undertaken to ensure that future erosion risk is understood and appropriate mitigation measures can be put in place.

The use of LiDAR and aerial photography surveys can assist this process and consideration should be given to re-visiting this assessment using future aerial surveys to document any changes that may be evident from deeper ploughing or surveying at a different time of the year.

Table 4.1. Summary of mapped archaeological anomalies

Feature	Description	Area (sq m)	Feature Recognised			Centre of Feature		Local Authority	SMP Unit
			CASI	LiDAR	Photo	Easting	Northing		
1	Rectangular crop mark	8,900	No	Yes	No	426008	616968	NCC	MA10
2	Bank enclosure	6,300	Yes	Yes	No	423607	625736	NCC	MA9
3	Building platform	5,900	Yes	Yes	No	423561	625754	NCC	MA9
4	Bank enclosure	3,500	Yes	Yes	No	423734	625689	NCC	MA9
5	Clear structural crop marks adjacent to scheduled monument	12,400	No	Yes	No	408631	640649	NCC	MA4
6	Clear crop mark adjacent to known scheduled monument	8,600	No	Yes	No	408682	640949	NCC	MA4
7	Crop marks adjacent to existing scheduled monument	33,500	No	Yes	No	408462	641028	NCC	MA4
8	Crop mark - possible enclosure	1,100	No	No	Yes	482699	514061	SBC	MA21
9	Relict field boundary	800	No	Yes	No	480638	515881	SBC	MA21
10	Probable former railway	15,600	No	Yes	Yes	477379	518647	R&CBC	MA18
11	Many crop marks - possible quarrying	91,800	No	Yes	No	475774	519109	R&CBC	MA18
12	Regular crop mark - possibly modern	400	No	No	Yes	475222	519390	R&CBC	MA18
13	Mound	1,000	Yes	No	Yes	441427	553220	SDC	MA8
14	Crop mark – possible enclosure	4,200	No	No	Yes	439857	560634	STDC	MA6
15	Crop mark	200	No	No	Yes	439775	560695	STDC	MA6
16	Rectangular crop mark	20,100	No	No	No	439894	560772	STDC	MA6
17	Regular-shaped mound. Probably modern	800	No	Yes	Yes	430796	587770	NCC	MA20
18	Faint crop mark. Possibly modern ploughing	3,400	No	No	Yes	429543	590429	NCC	MA19
19	Rectangular darkening - could be modern	2,900	No	No	Yes	429617	590532	NCC	MA19
20	Probable former water course or buried pipe	3,600	Yes	No	No	425564	604258	NCC	MA16
21	Rectangular linear structure, probably modern	17,000	Yes	No	No	425553	604101	NCC	MA16
22	Probable building foundation platform	400	No	Yes	No	424700	609451	NCC	MA13
23	Rectilinear boundary	1,500	No	Yes	Yes	523554	472044	ERYC	Ma33
24	Bank or mound	600	No	Yes	Yes	520004	473792	ERYC	MA33
25	Mound	400	No	Yes	Yes	519915	473819	ERYC	MA33

Feature	Description	Area (sq m)	Feature Recognised			Centre of Feature		Local Authority	SMP Unit
			CASI	LiDAR	Photo	Easting	Northing		
26	Bank or mount	1,400	No	Yes	Yes	519823	473822	ERYC	MA33
27	Crop marks	293,700	No	No	Yes	502437	494420	SBC	MA26
28	Two platforms, possibly a natural feature	1300	No	Yes	Yes	501031	497034	SBC	MA25
29	Possible earthwork or dyke	1600	No	No	Yes	499518	499691	SBC	MA25
30	Circular crop mark. Possible barrow?	1000	No	No	Yes	497731	500937	SBC	MA25
31	Possible round barrow	300	No	No	Yes	498281	501305	SBC	MA25
32	Platform structure, probably natural	7400	No	Yes	Yes	482970	515900	SBC	MA21
			6	18	19				


498000
501500
501000
500500
30
31
200
100
0
200 Metres
Legend
Mapped Anomoly
Scheduled Monument

Figure 4.1. Mapped anomalies adjacent to existing barrow mounds visible in photography only, near Ravenscar.

Figure 4.2. Crop marks visible in aerial photograph only, north of Scalby.

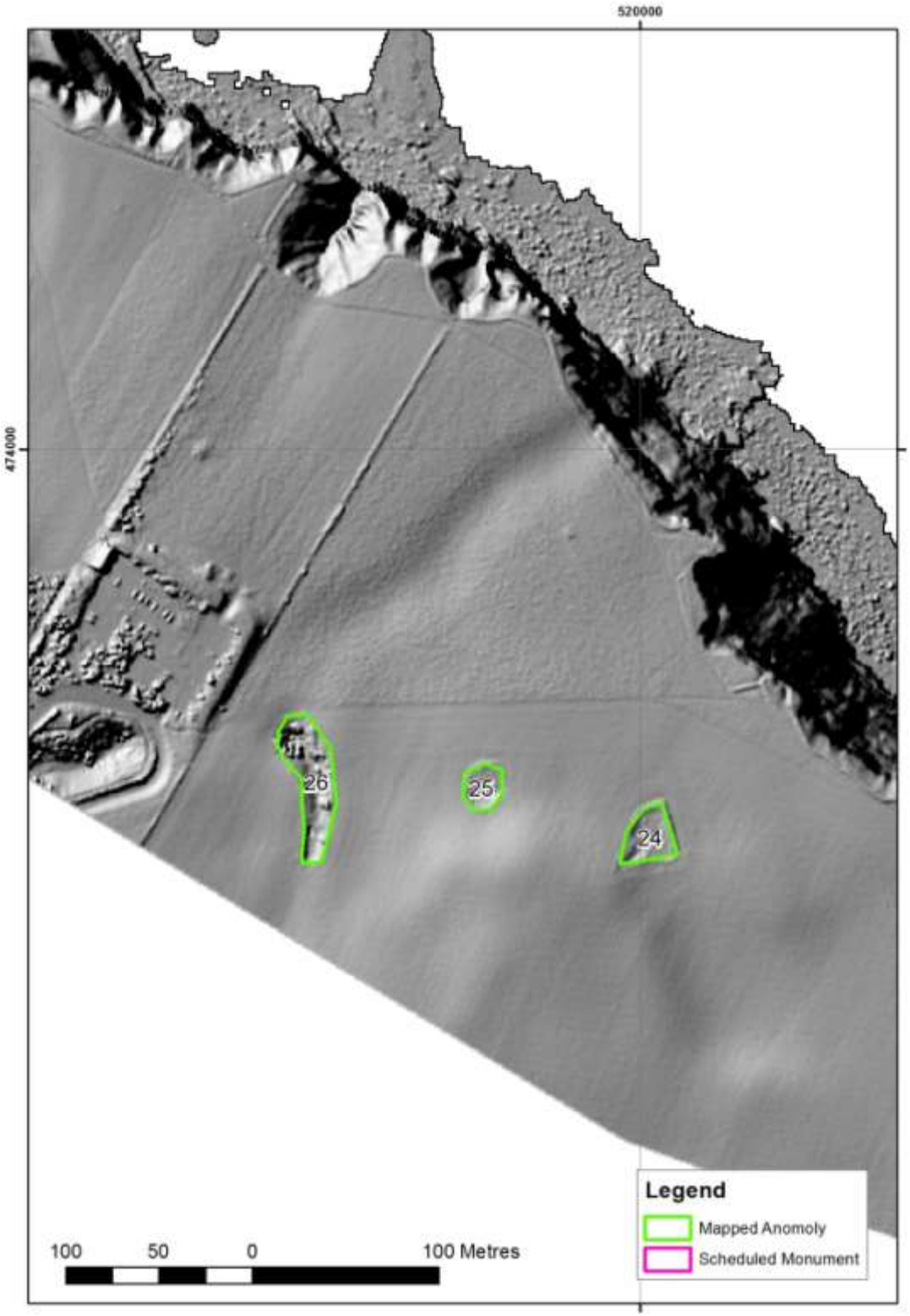
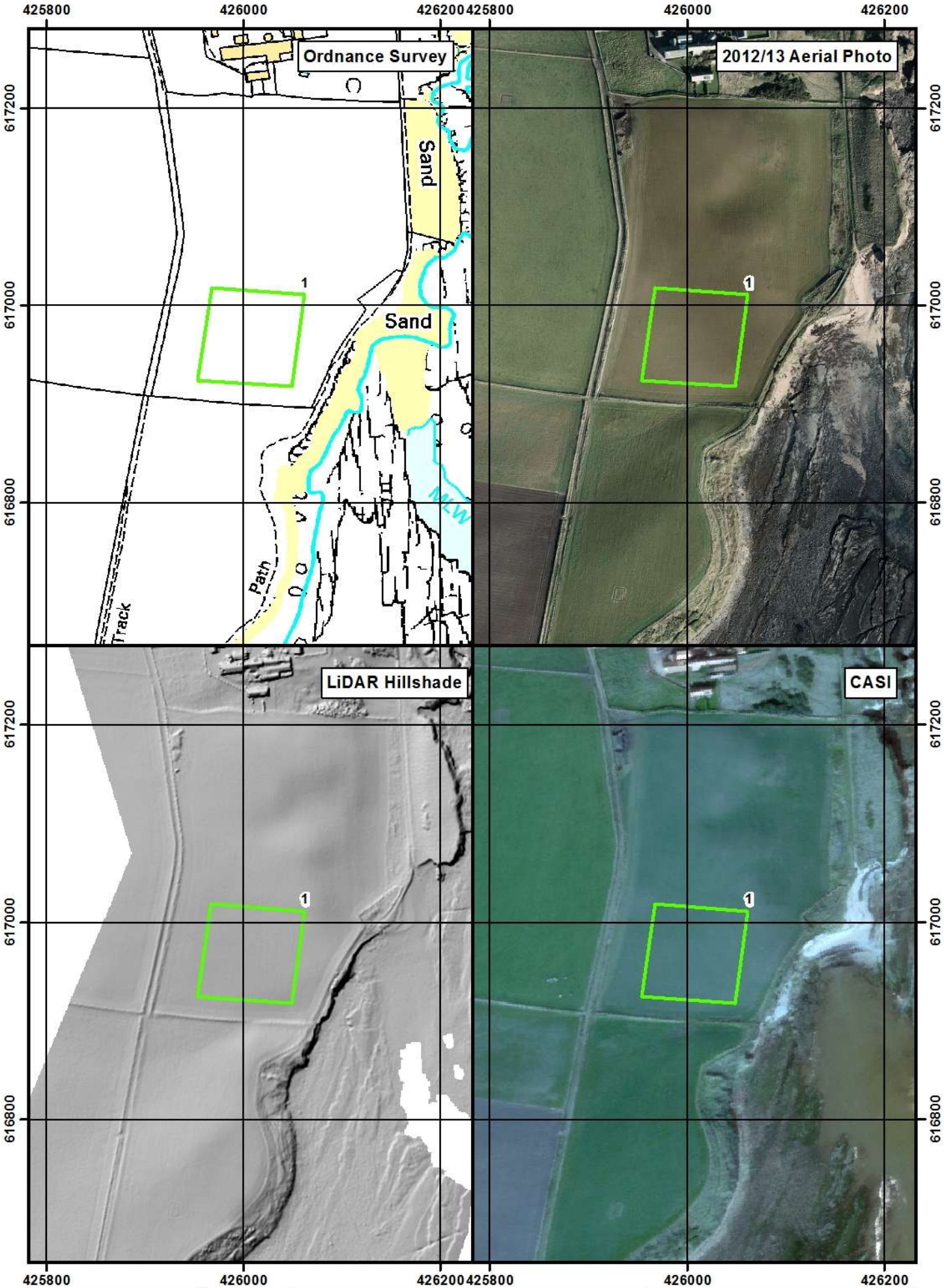


Figure 4.3. Mounds and ditches visible in LiDAR and photograph, north of Flamborough Head.

APPENDIX A

GIS data – mapped anomalies and English Heritage Scheduled Monuments



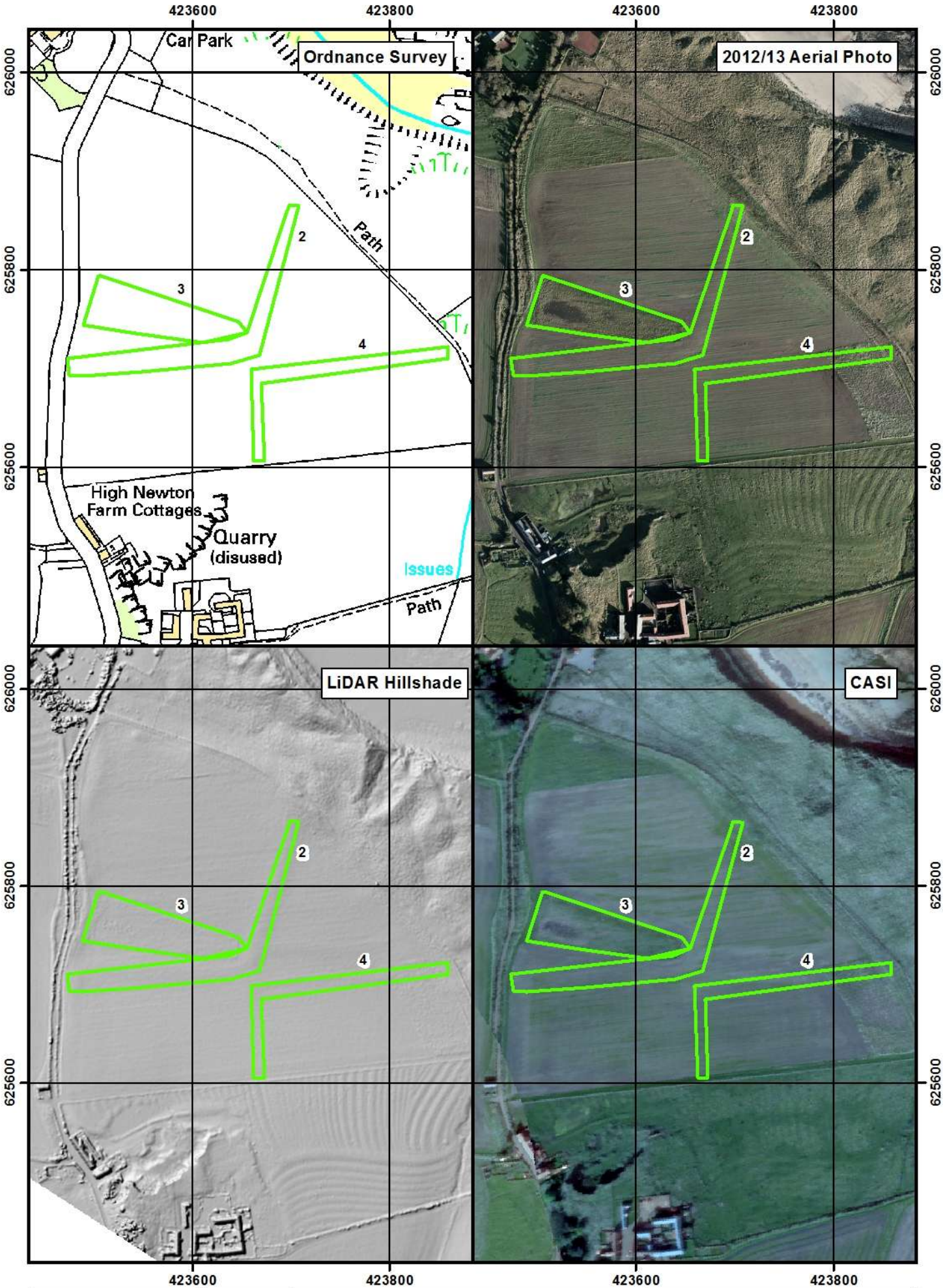
Feature 1: Rectangular Crop Mark

N

0 50 100 150 200 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



Features 2, 3 & 4:
Bank Enclosure (2)
Building Platform (3)
Bank Enclosure (4)

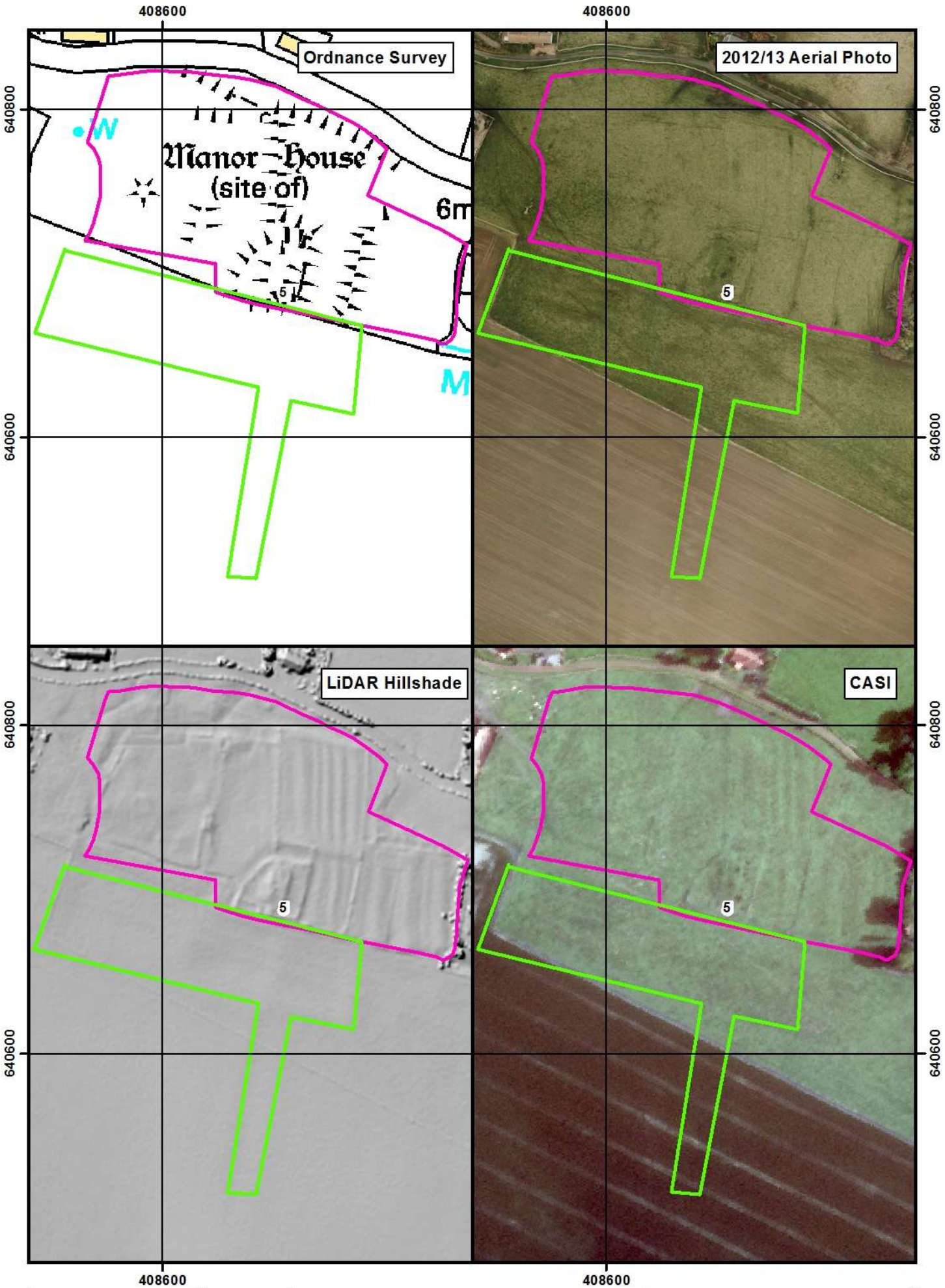
N

0 50 100 150 200 Metres

Legend

Mapped Anomaly

Scheduled Monument



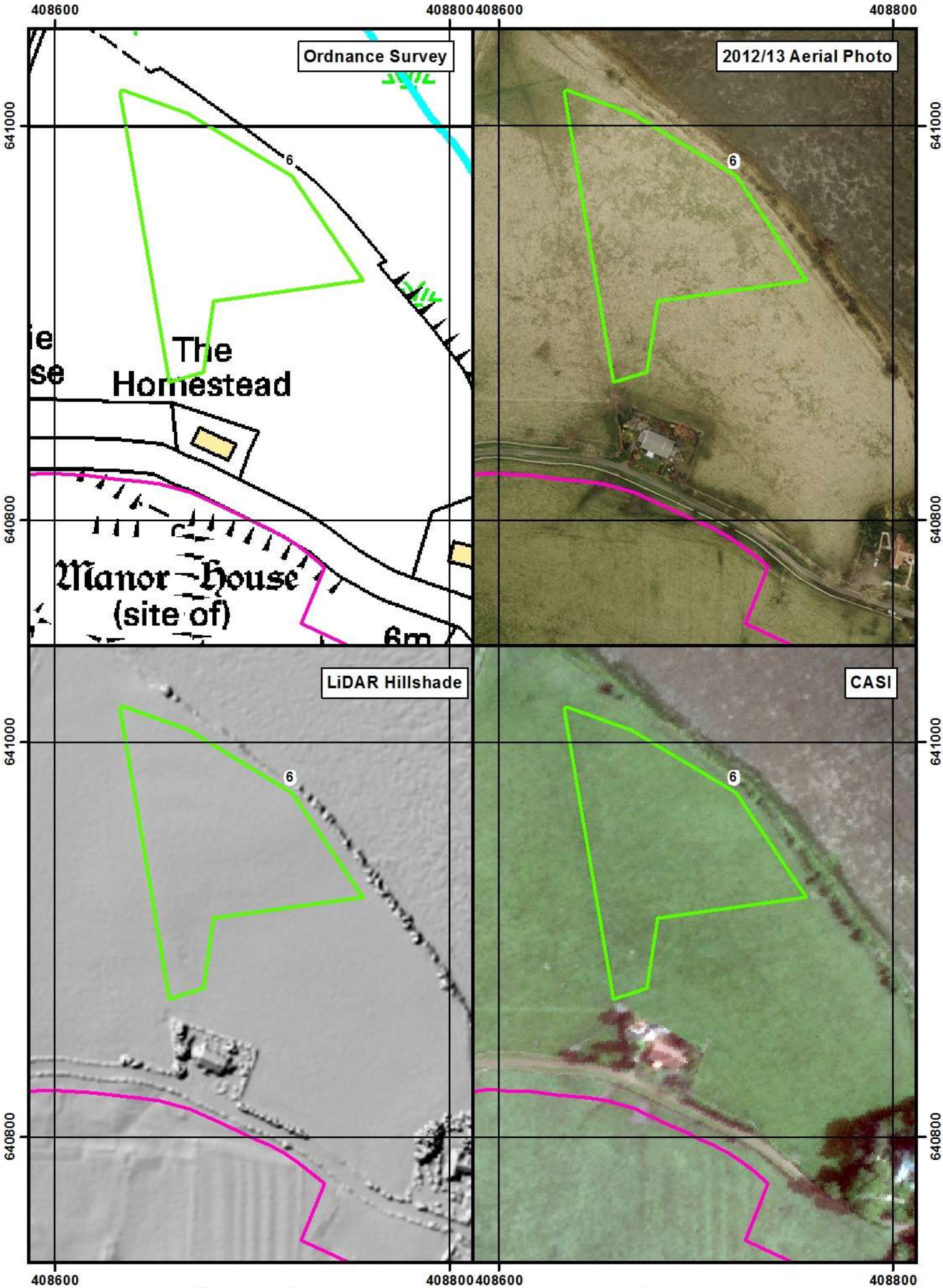
Feature 5: Clear Structural Crop Marks adjacent to Scheduled Monument

N

0 50 100 150 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



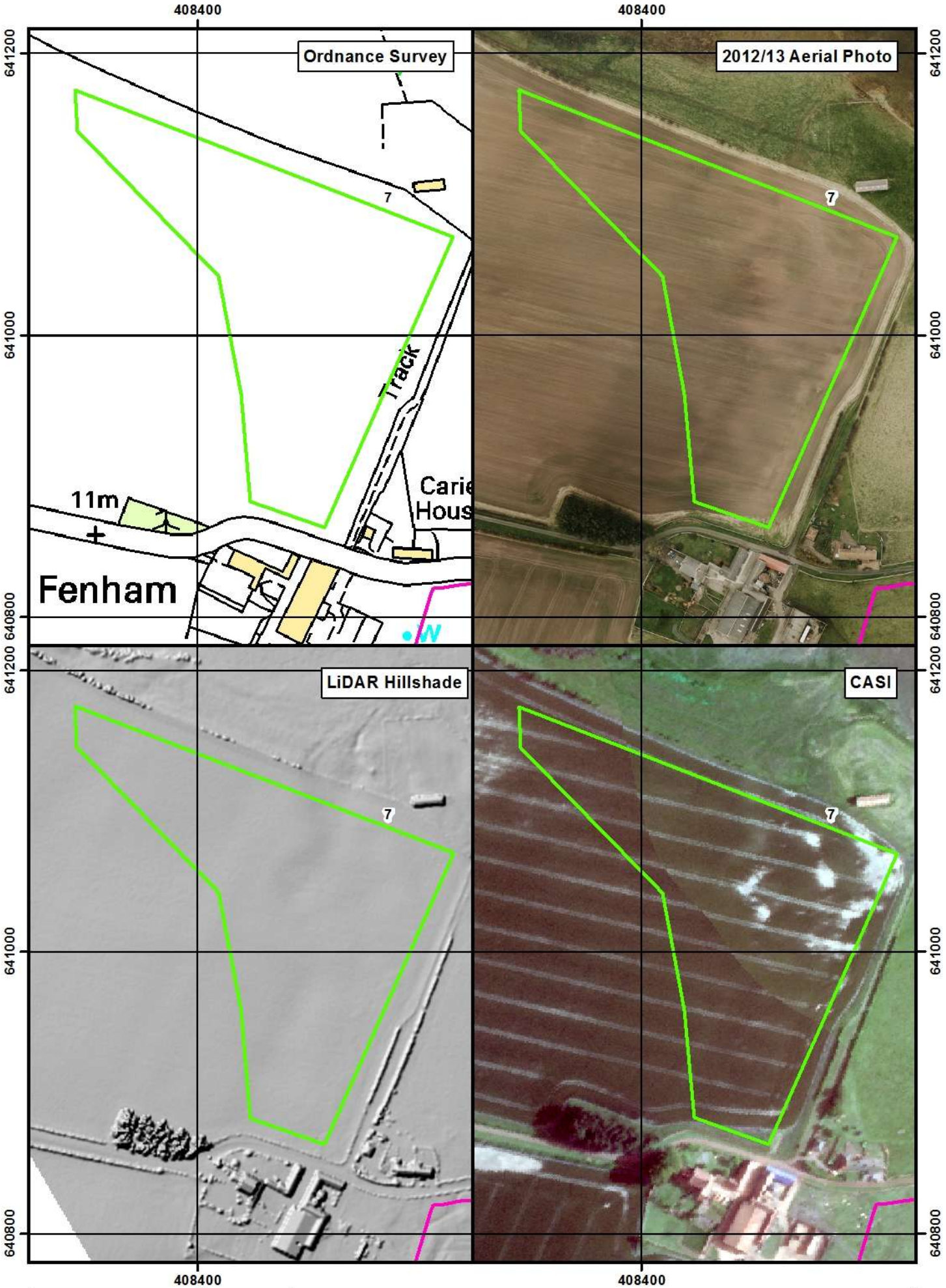
Feature 6: Clear Structural Crop Marks adjacent to Known Scheduled Monument

N

0 25 50 75 100 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



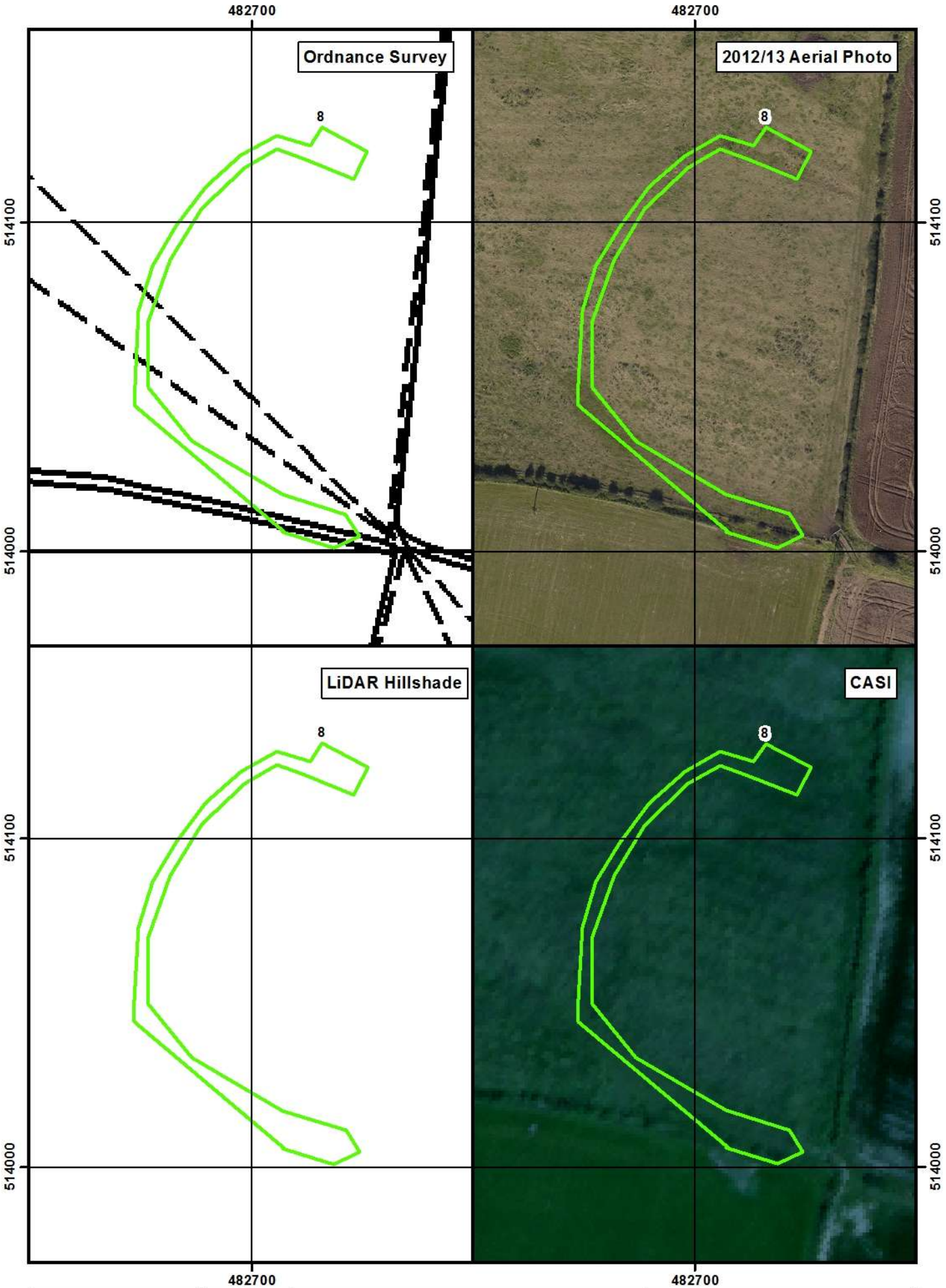
Feature 7: Crop Marks adjacent to Existing Scheduled Monument

N

0 50 100 150 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



Feature 8:
Crop Mark -
Possible Enclosure

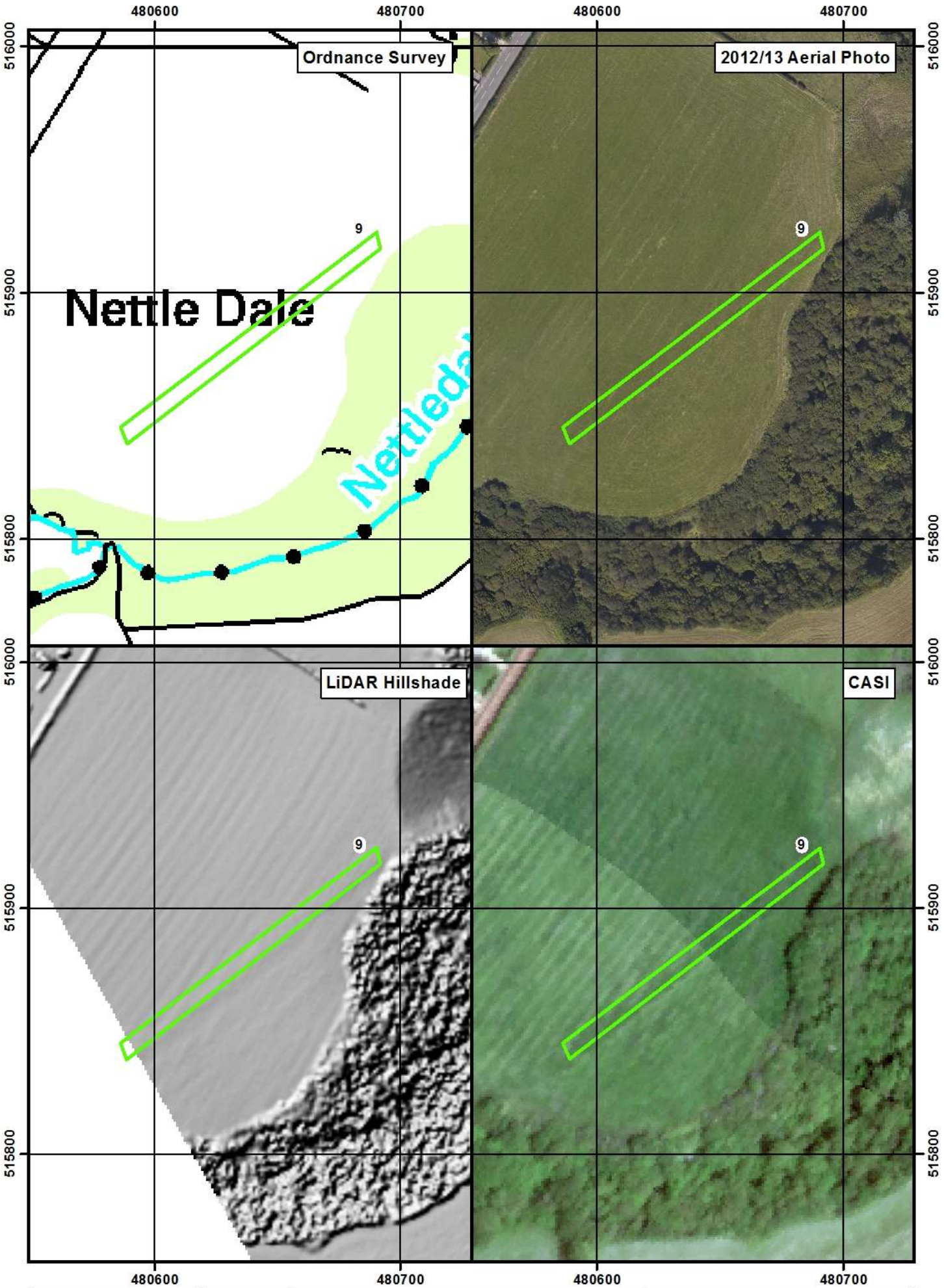
N

0 25 50 75 Metres

Legend

Mapped Anomaly

Scheduled Monument



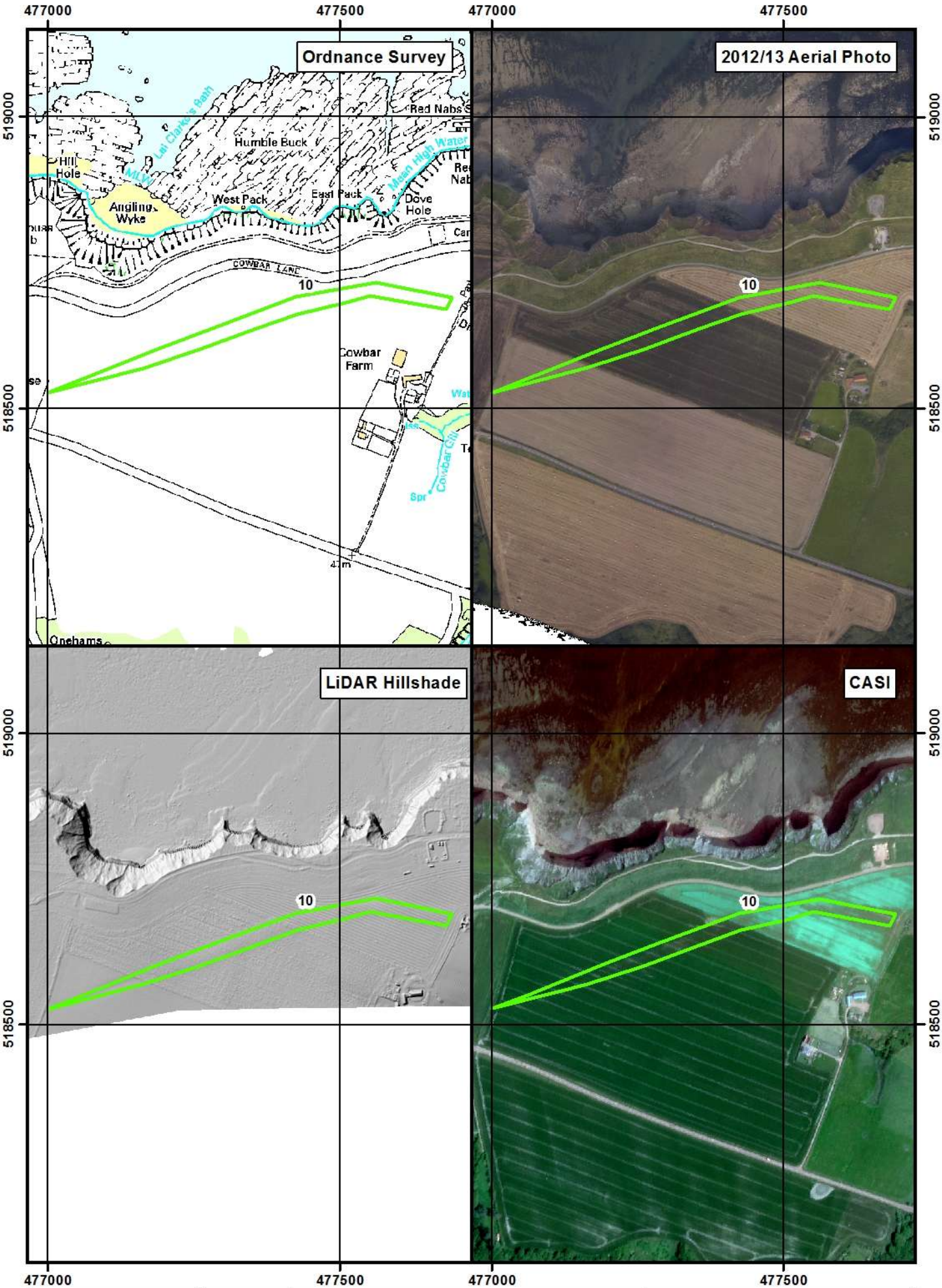
Feature 9: Relict Field Boundary

N

0 25 50 75 100 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



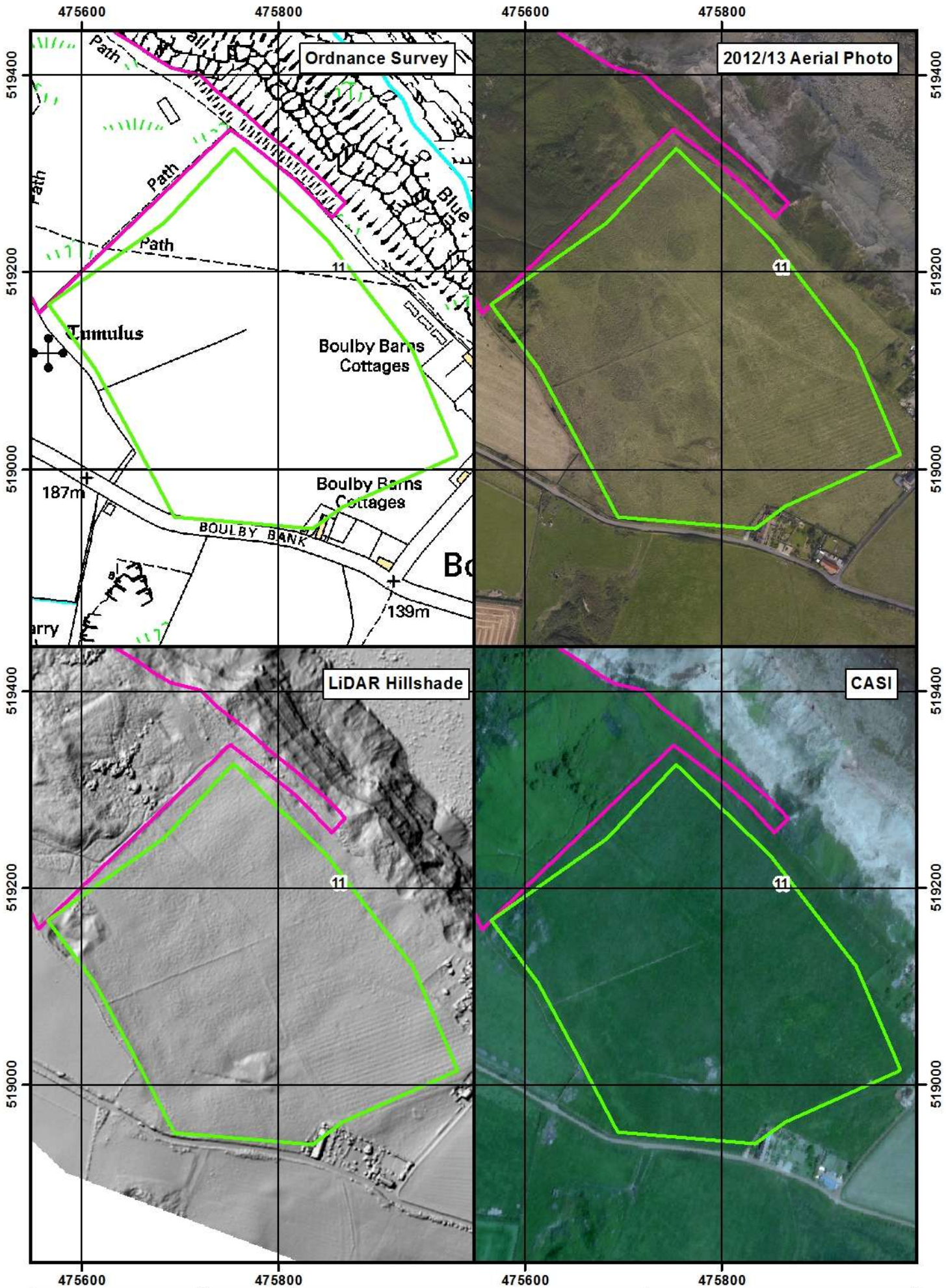
Feature 10: Probable Former Railway

N

0 100 200 300 400 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



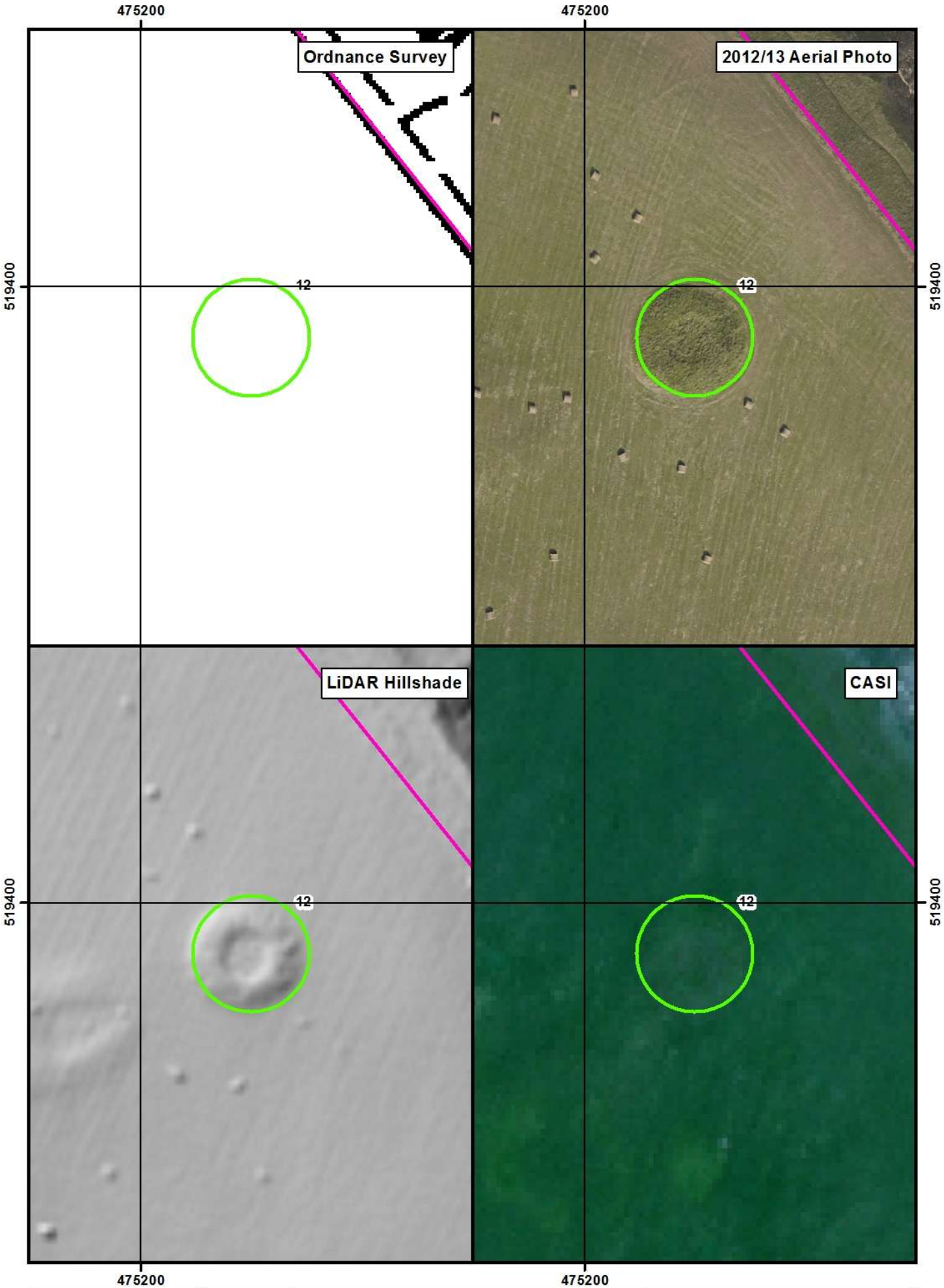
Feature 11:
Many Crop Marks - Possible Quarrying

N

0 50 100 150 200 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



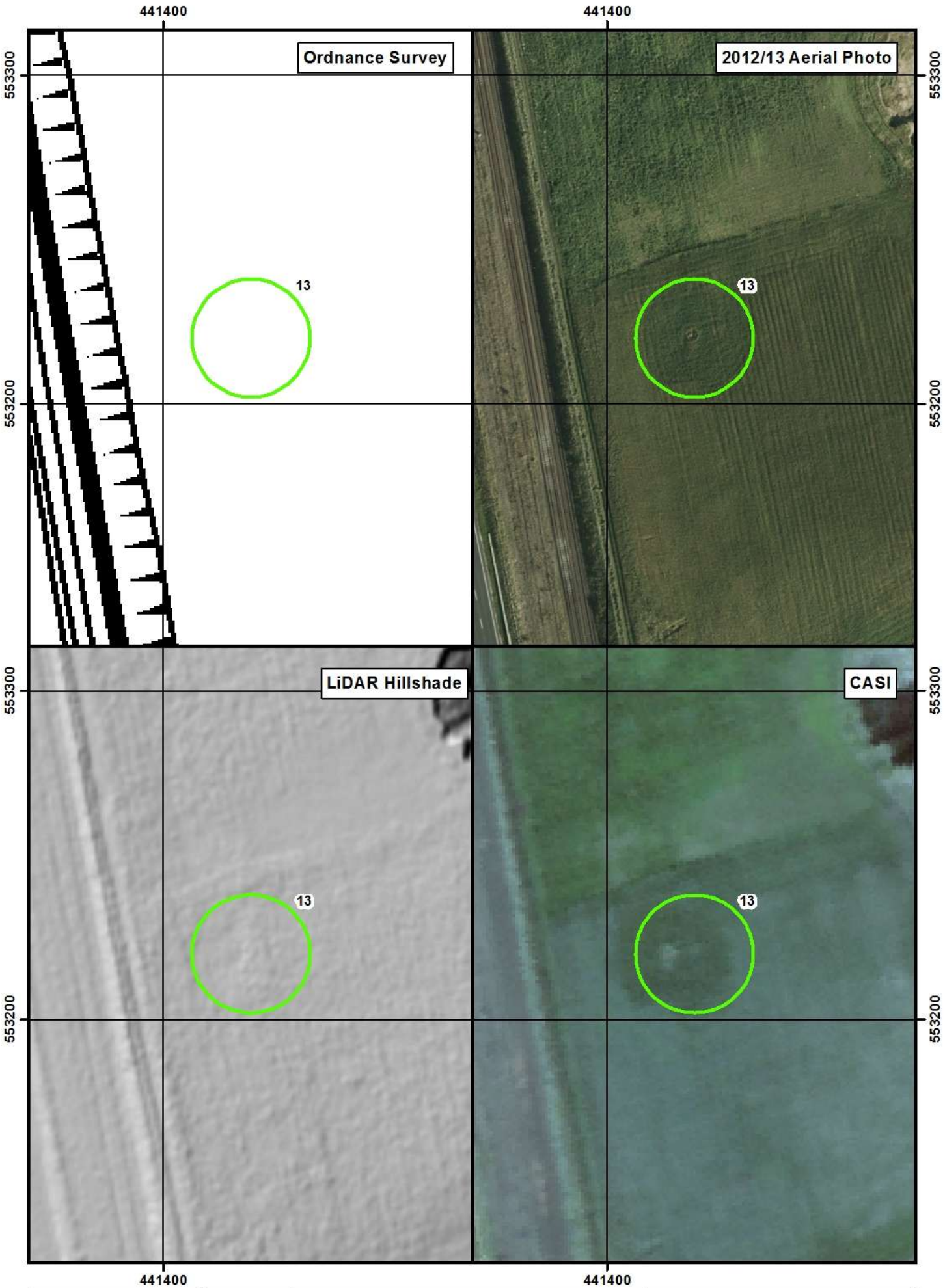
Feature 12:
Regular Crop Mark - Possibly Modern

N

0 25 50 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



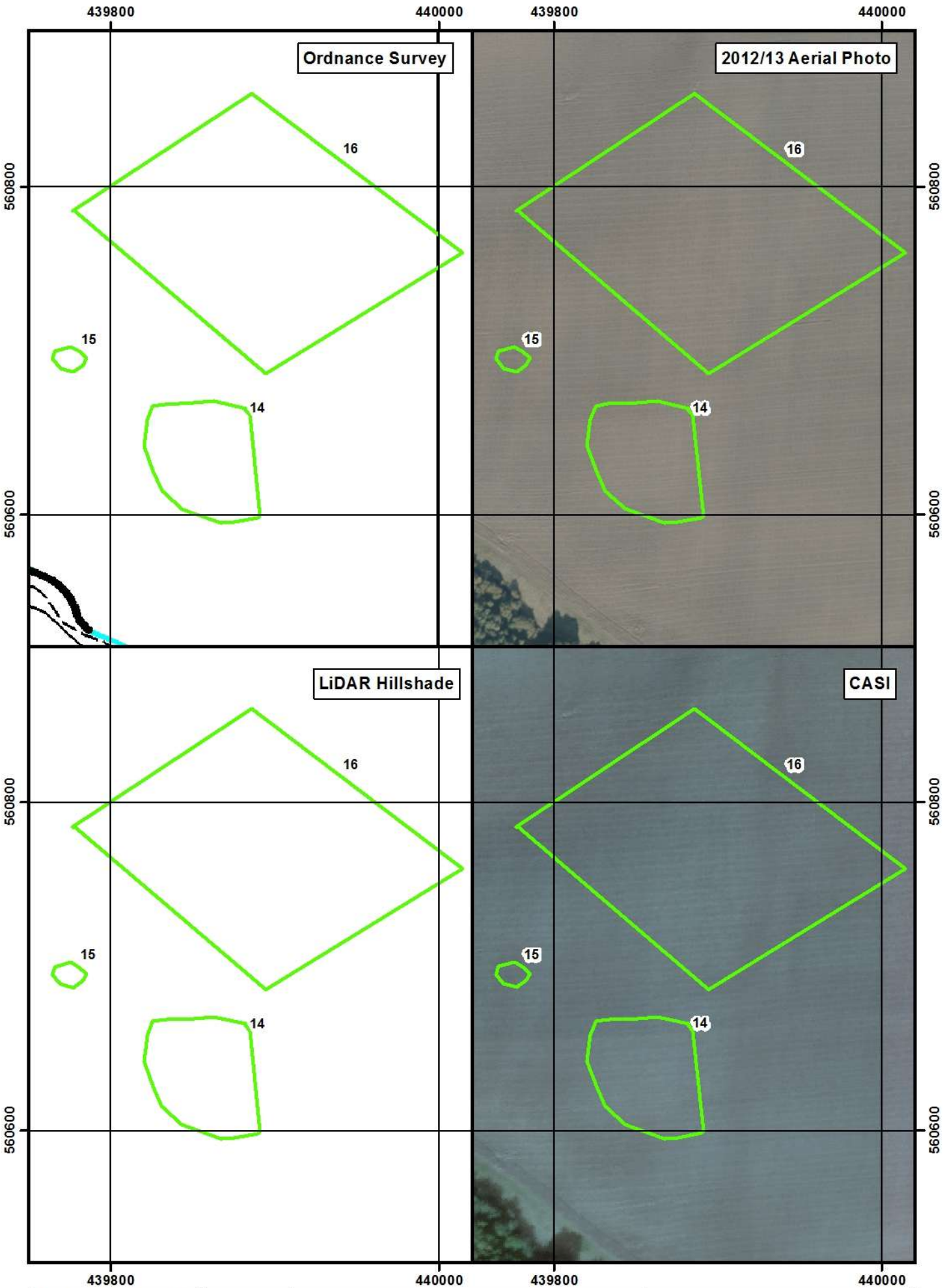
Feature 13: Mound

N

0 25 50 75 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



Features 14, 15, 16:
Crop Mark - Possible Enclosure (14)
Crop Mark (15)
Rectangular Crop Mark (16)

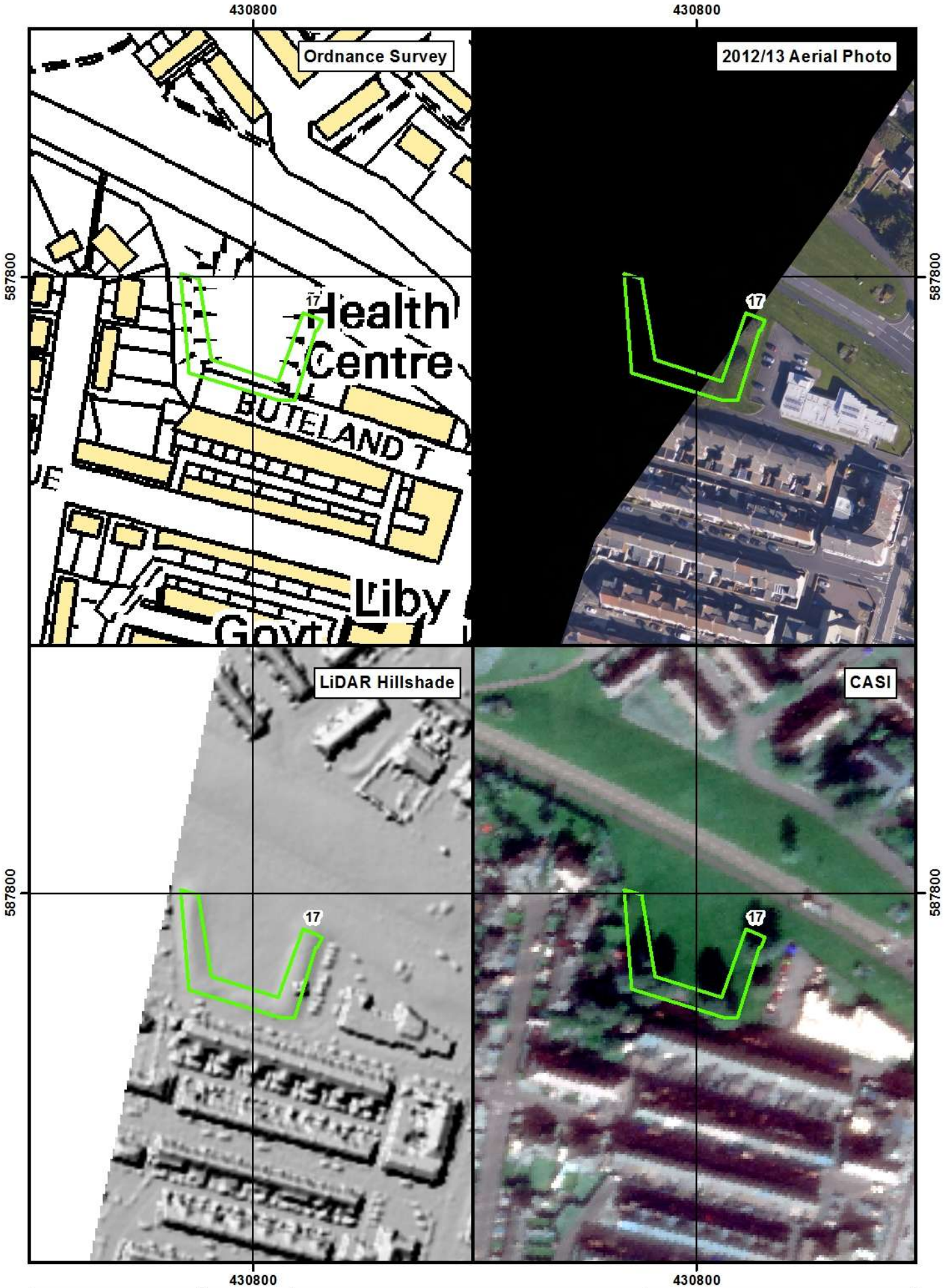
N

0 50 100 150 Metres

Legend

Mapped Anomaly

Scheduled Monument



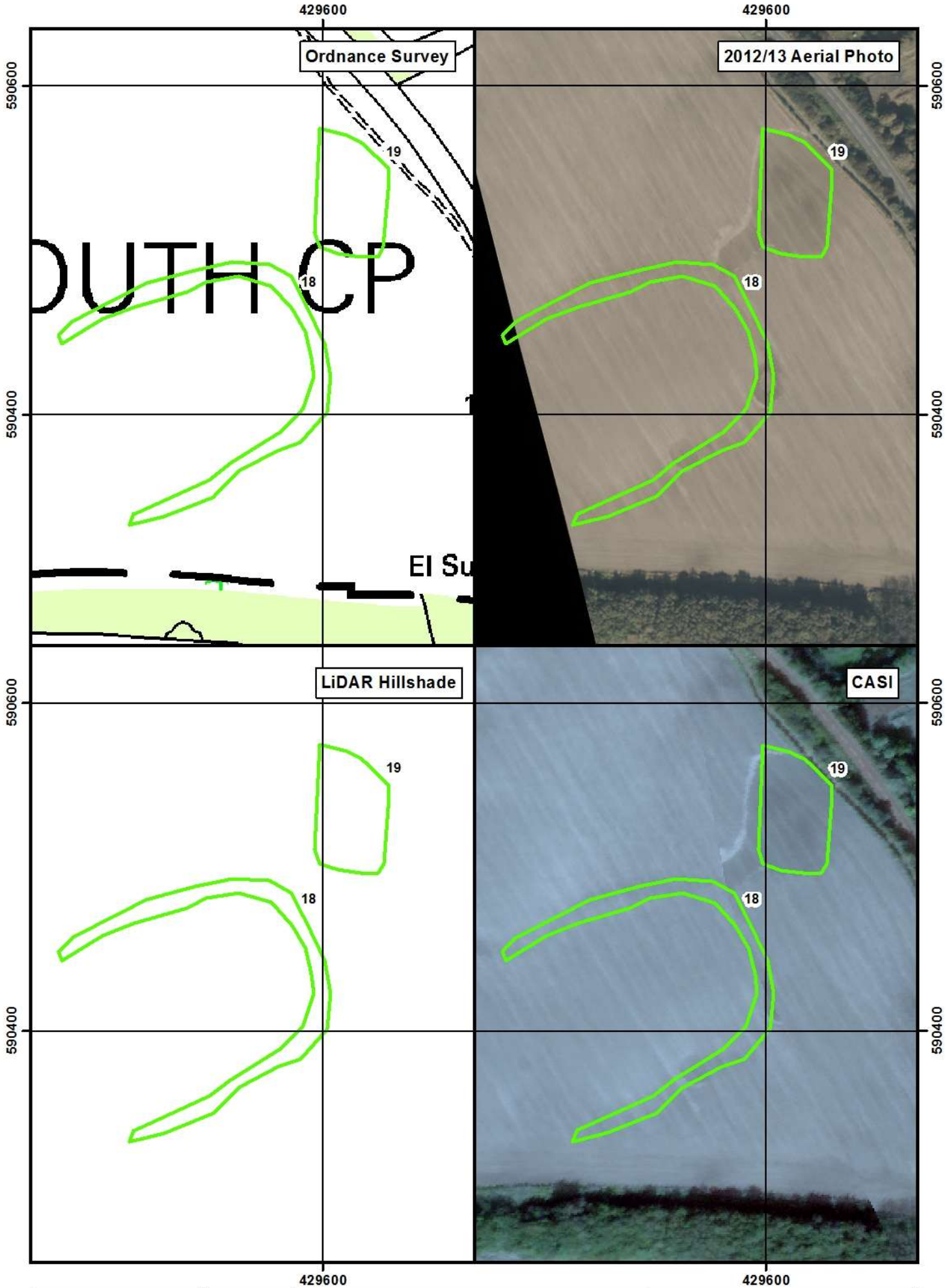
Feature 17:
Regular-shaped Mound
Probably Modern

N

0 25 50 75 100 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



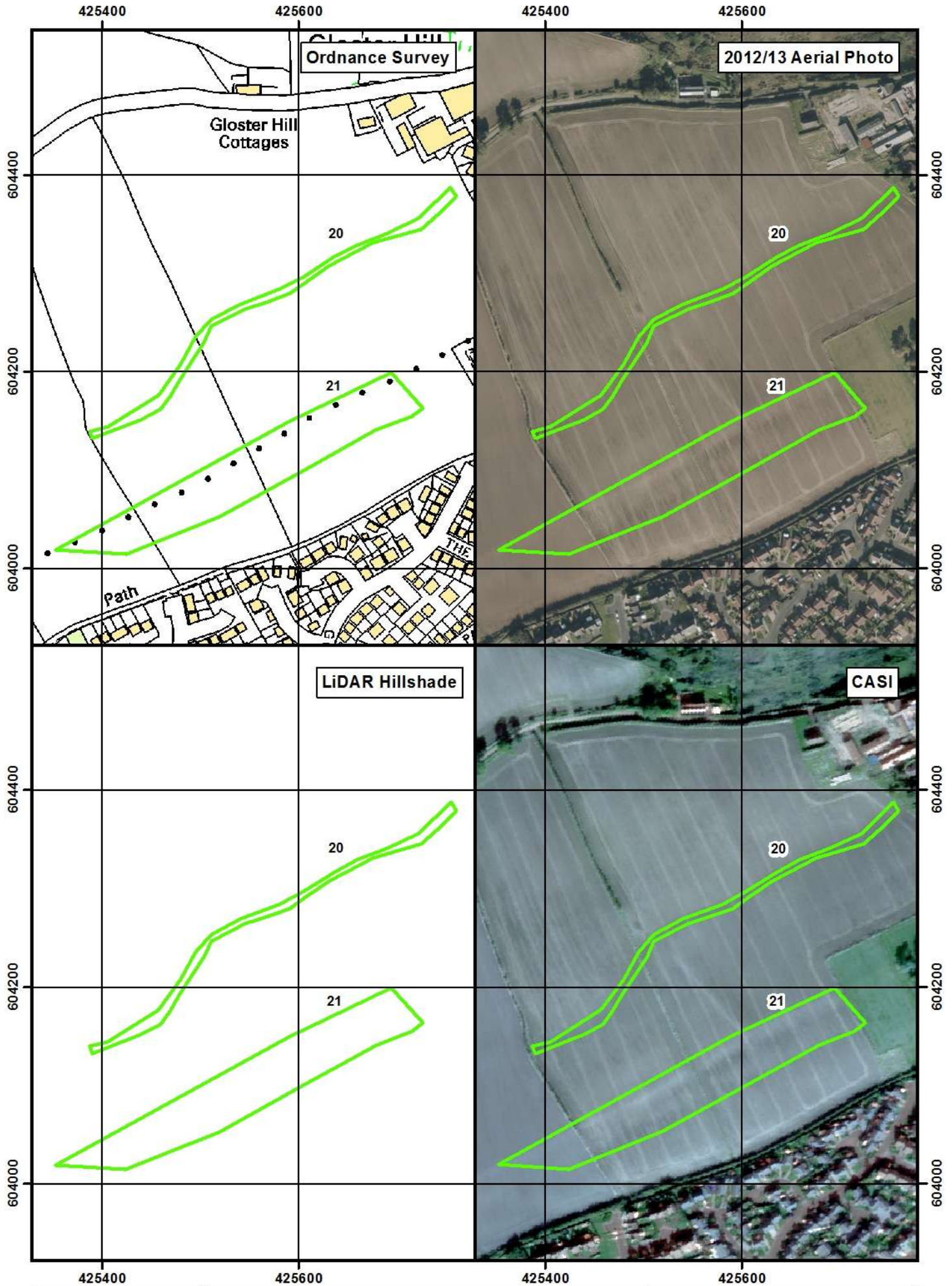
Features 18 and 19:
Faint Crop Mark - Possibly Modern Ploughing (18)
Rectangular Darkening Could be Modern (19)

N

0 50 100 150 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



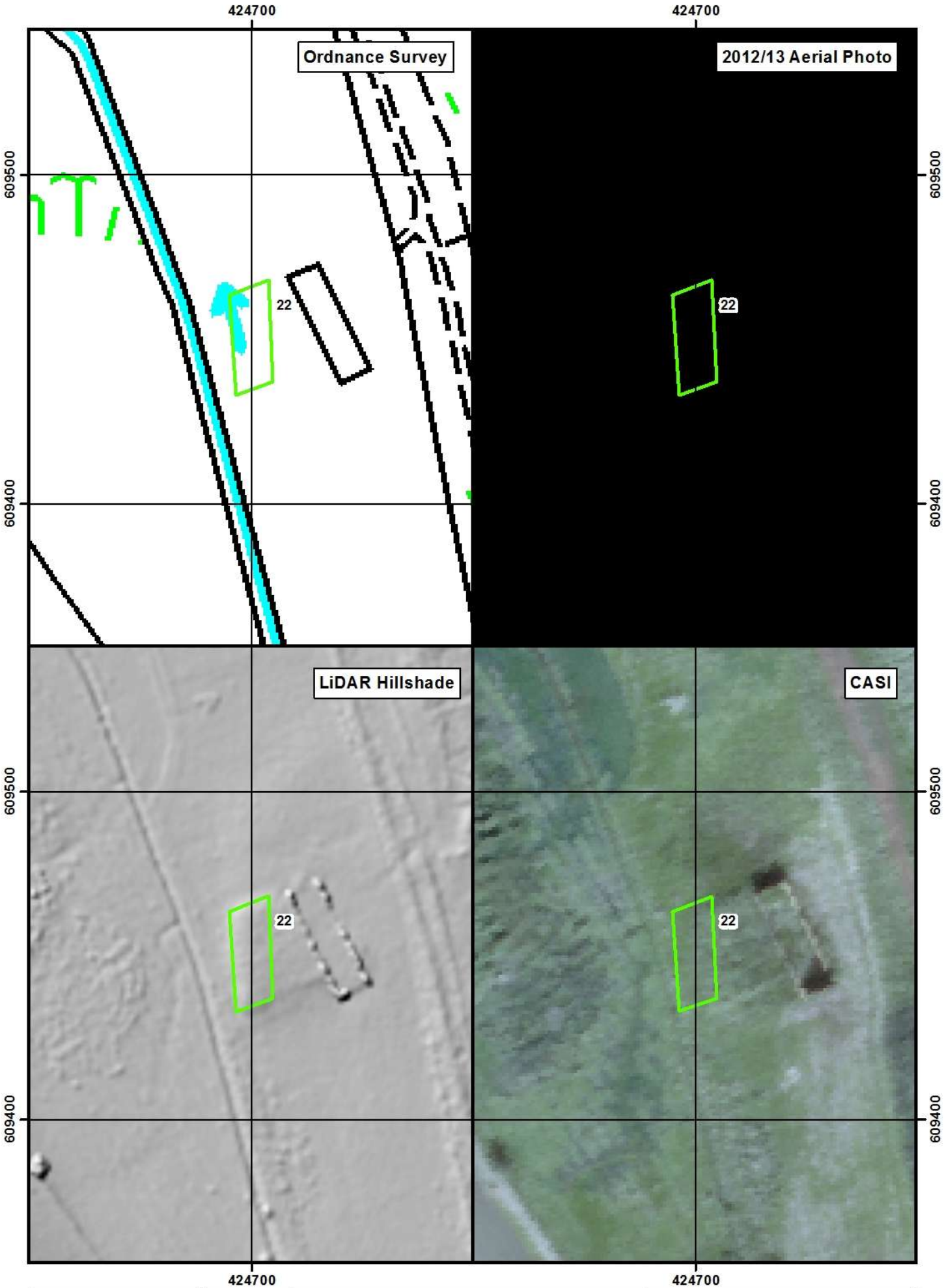
Features 20 and 21:
Probable Former Water Course (20)
Rectangular Linear Structure, Probably Modern (21)

N

0 50 100 150 200 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



Feature 22: Probable Building Foundation Platform

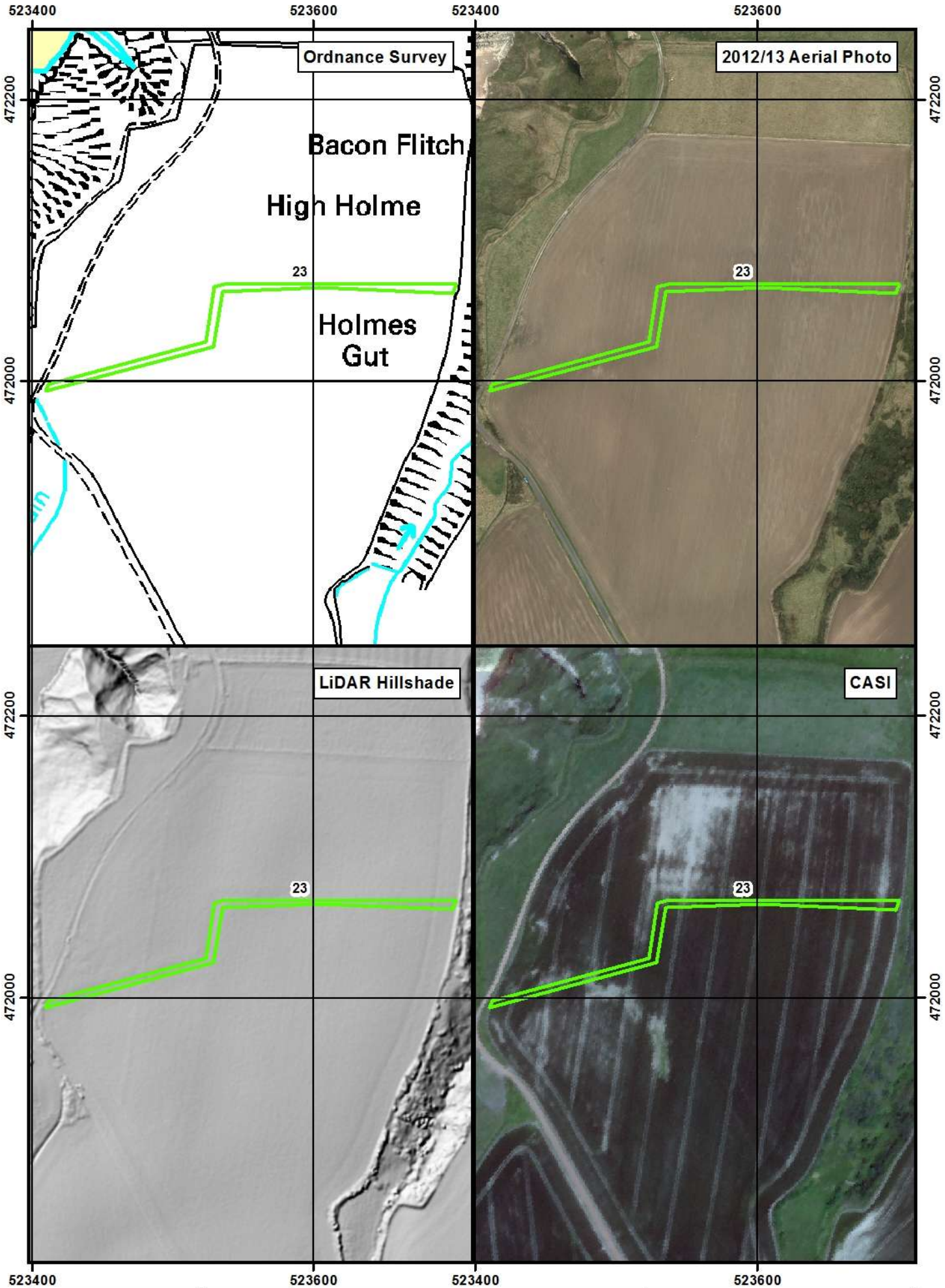
N

0 25 50 75 Metres

Legend

Mapped Anomaly

Scheduled Monument



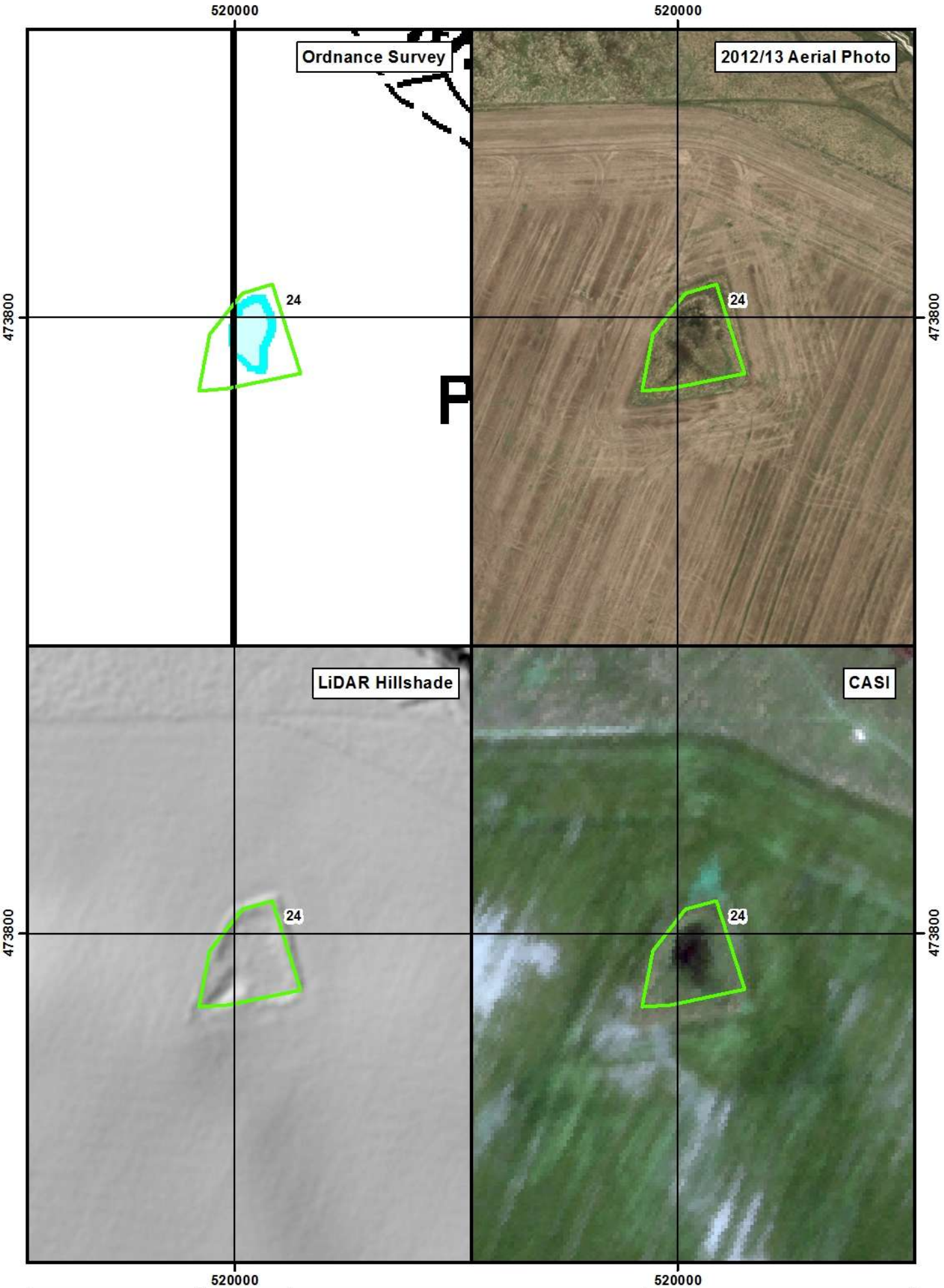
Feature 23: Rectilinear Boundary

N

0 50 100 150 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



Feature 24: Bank or Mound

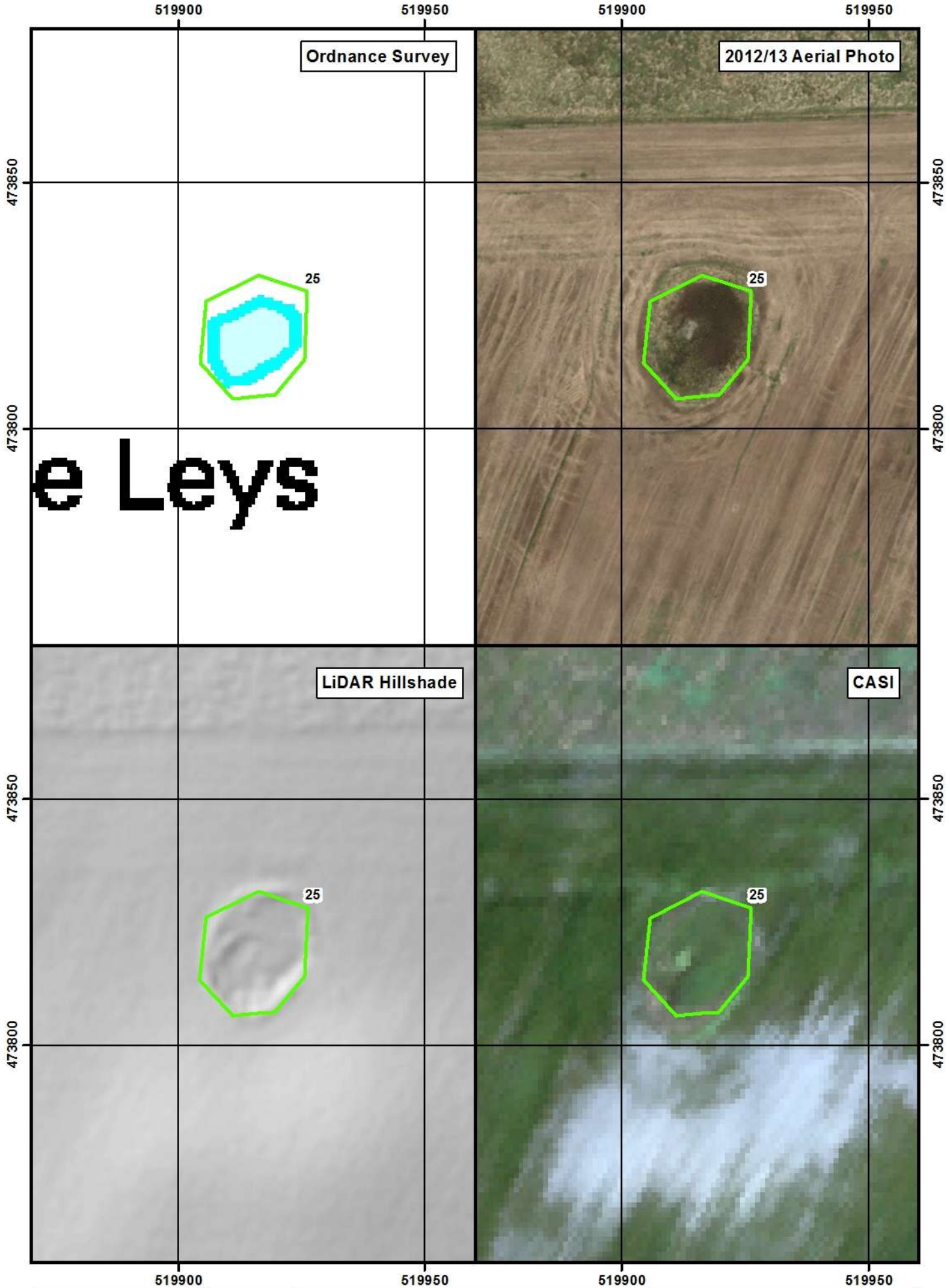
N

0 25 50 75 Metres

Legend

Mapped Anomaly

Scheduled Monument



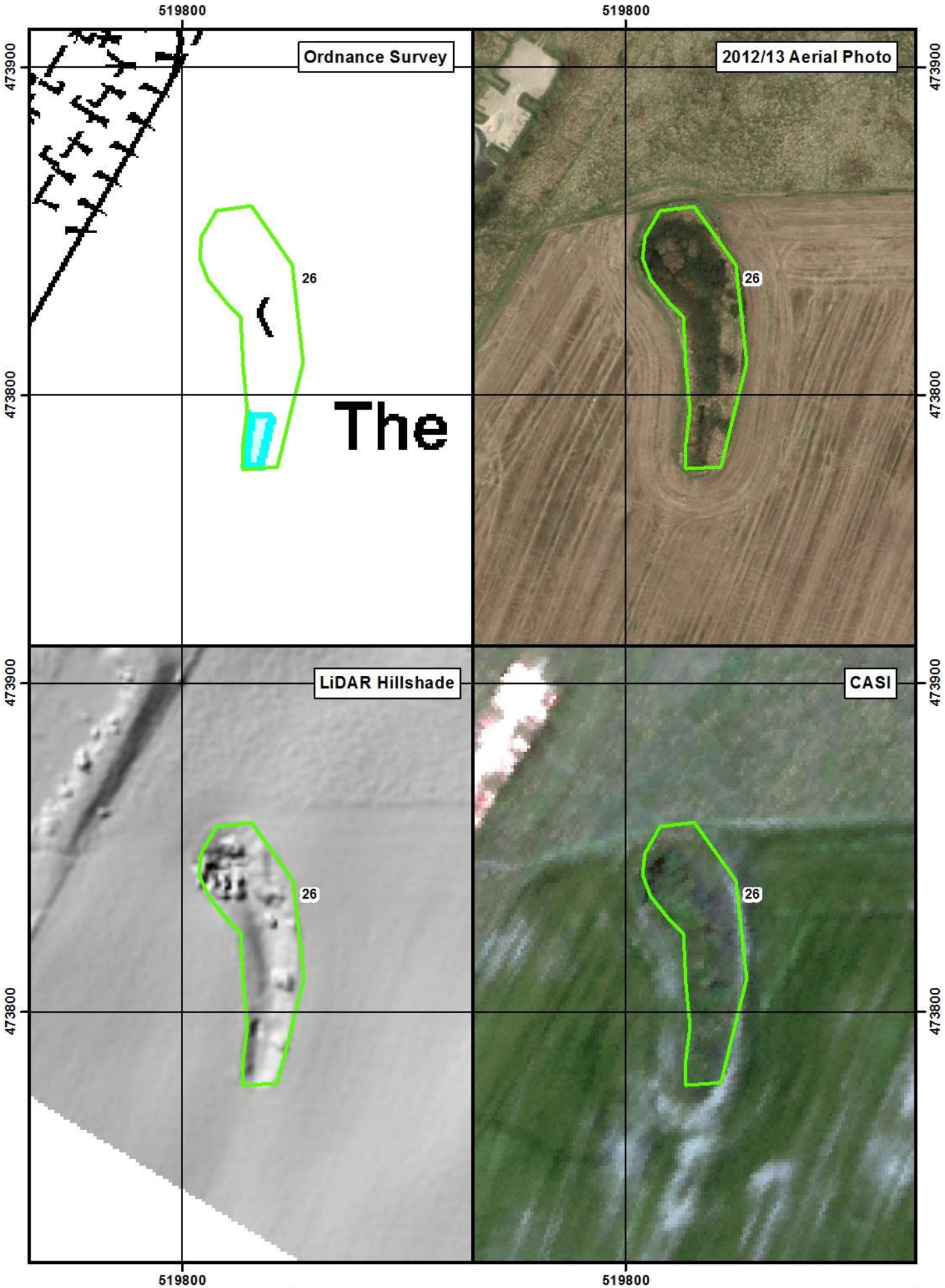
Feature 25: Mound

N

0 10 20 30 40 50 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



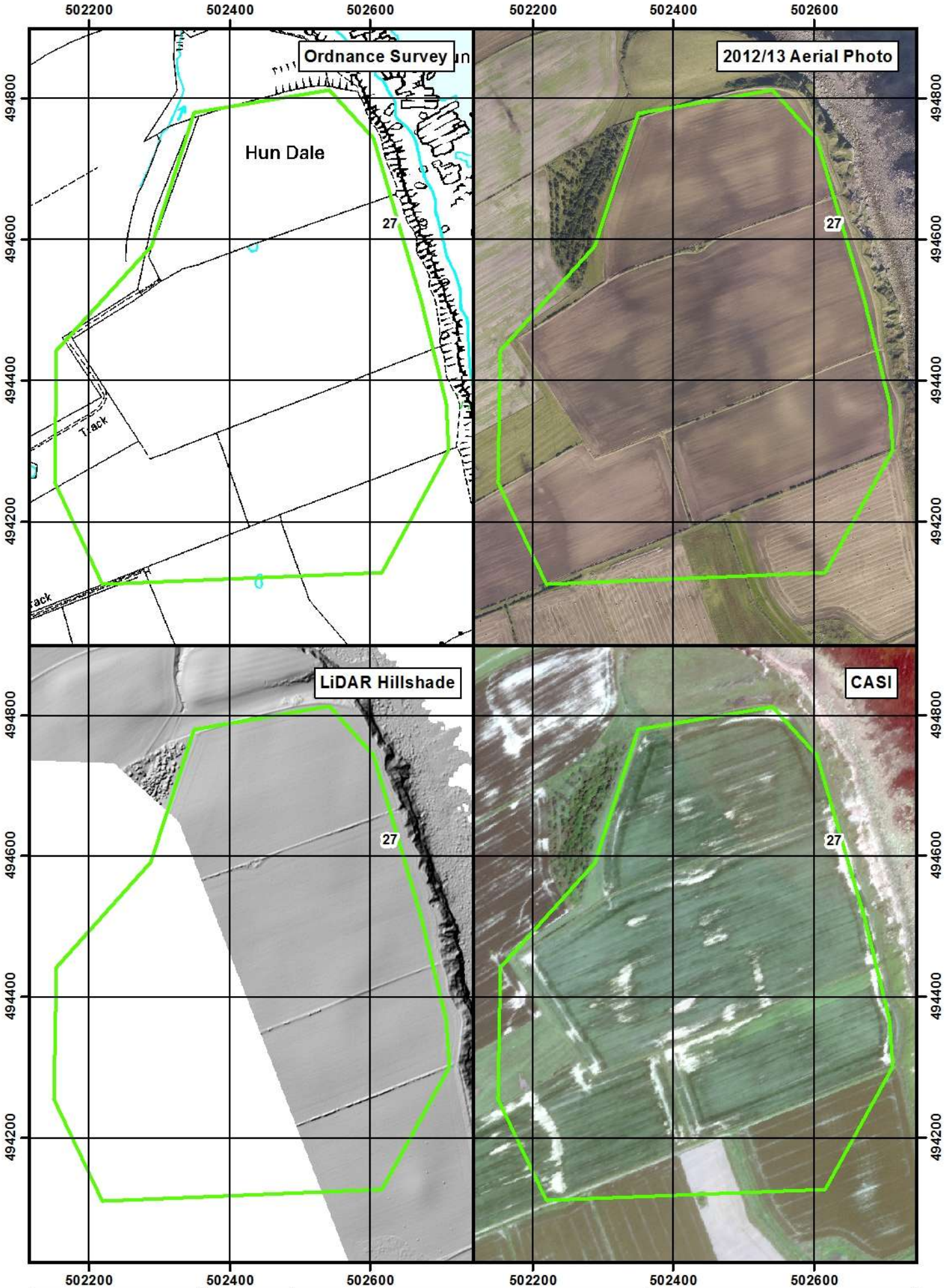
Feature 26:
Bank or Mound

N

0 25 50 75 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



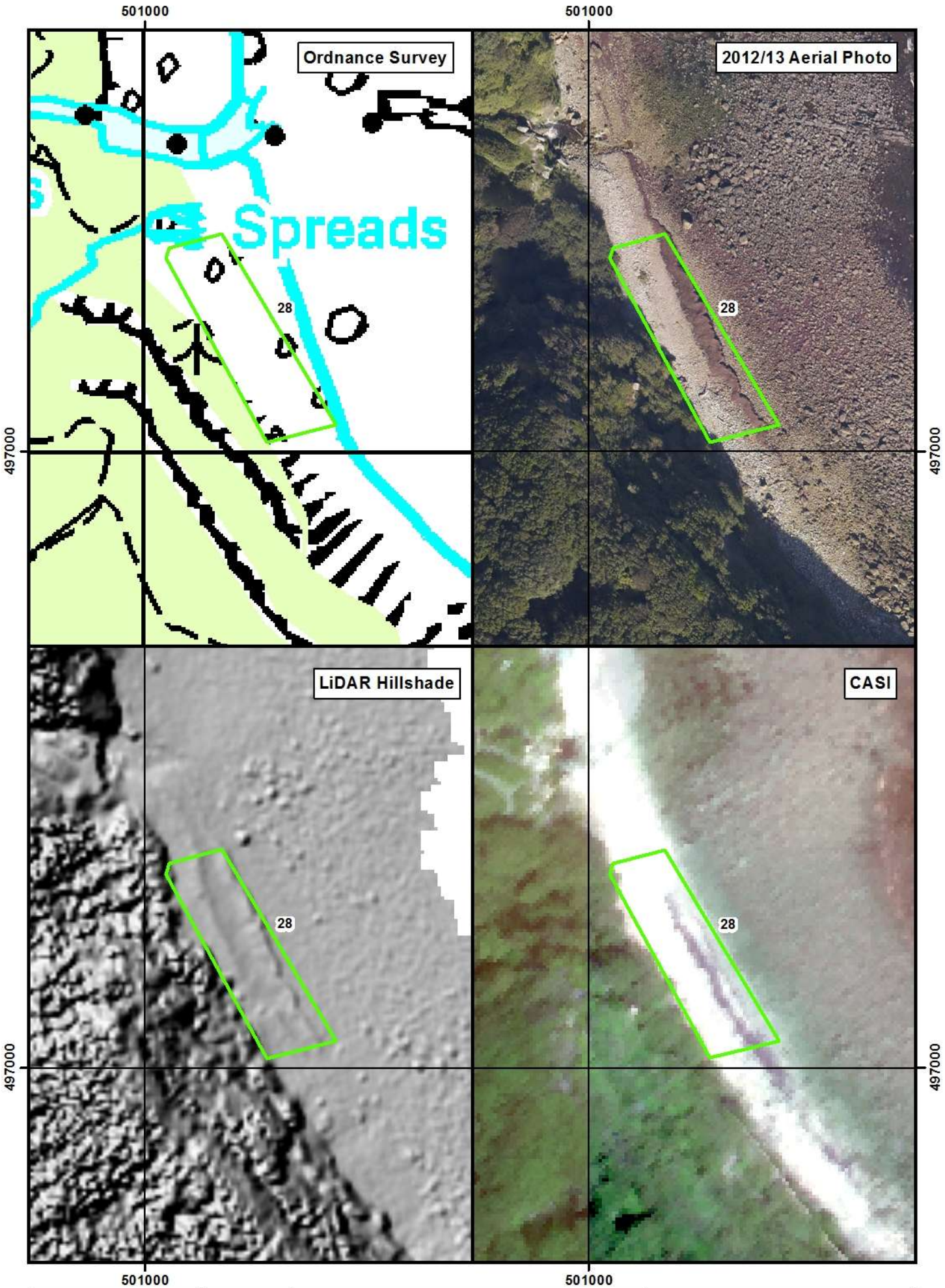
Feature 27: Crop Marks

N

0 100 200 300 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



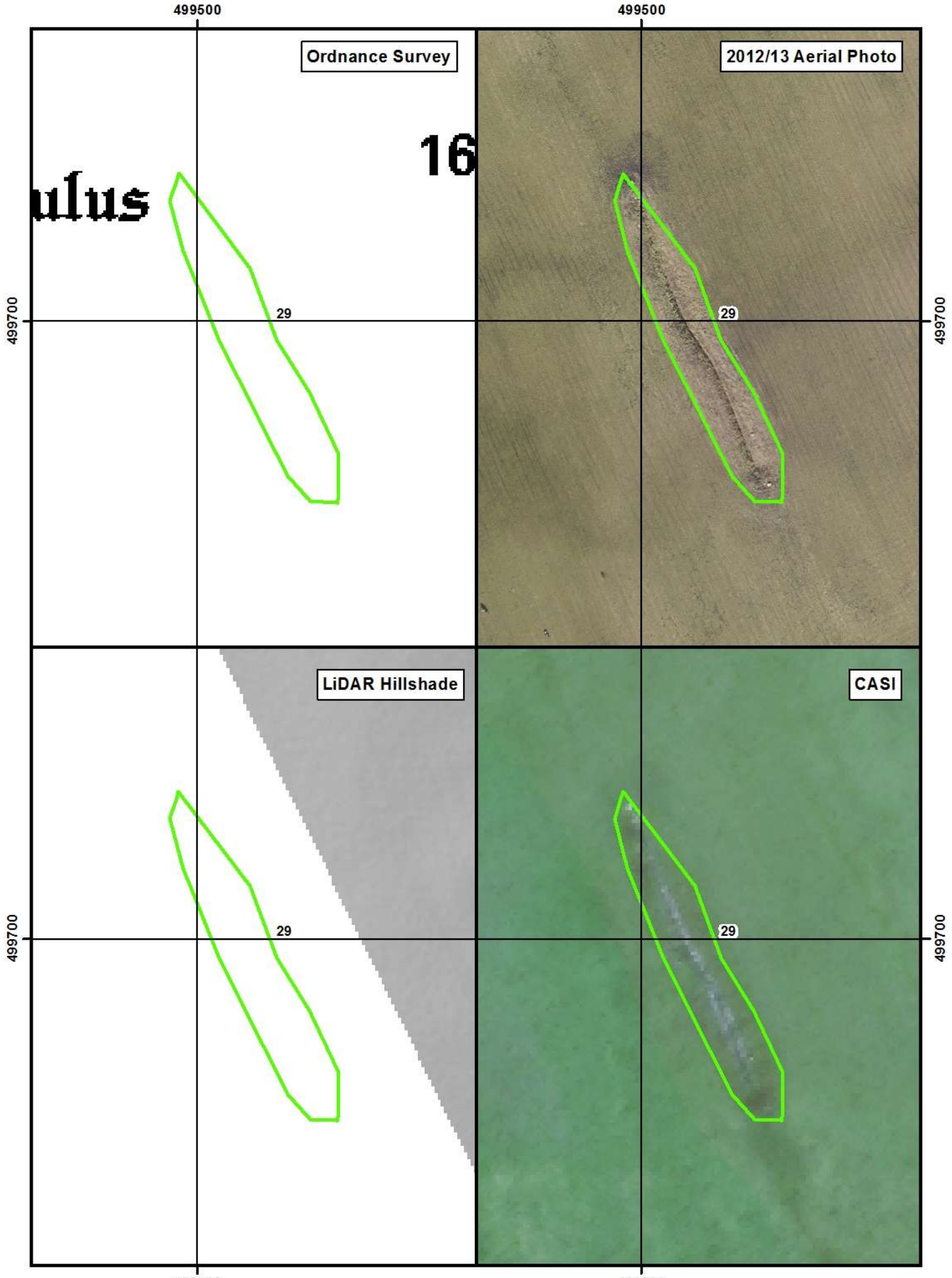
Feature 28: Two Platforms, Possibly a Natural Feature

N

0 25 50 75 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



Feature 29: Possible Earthwork or Dyke

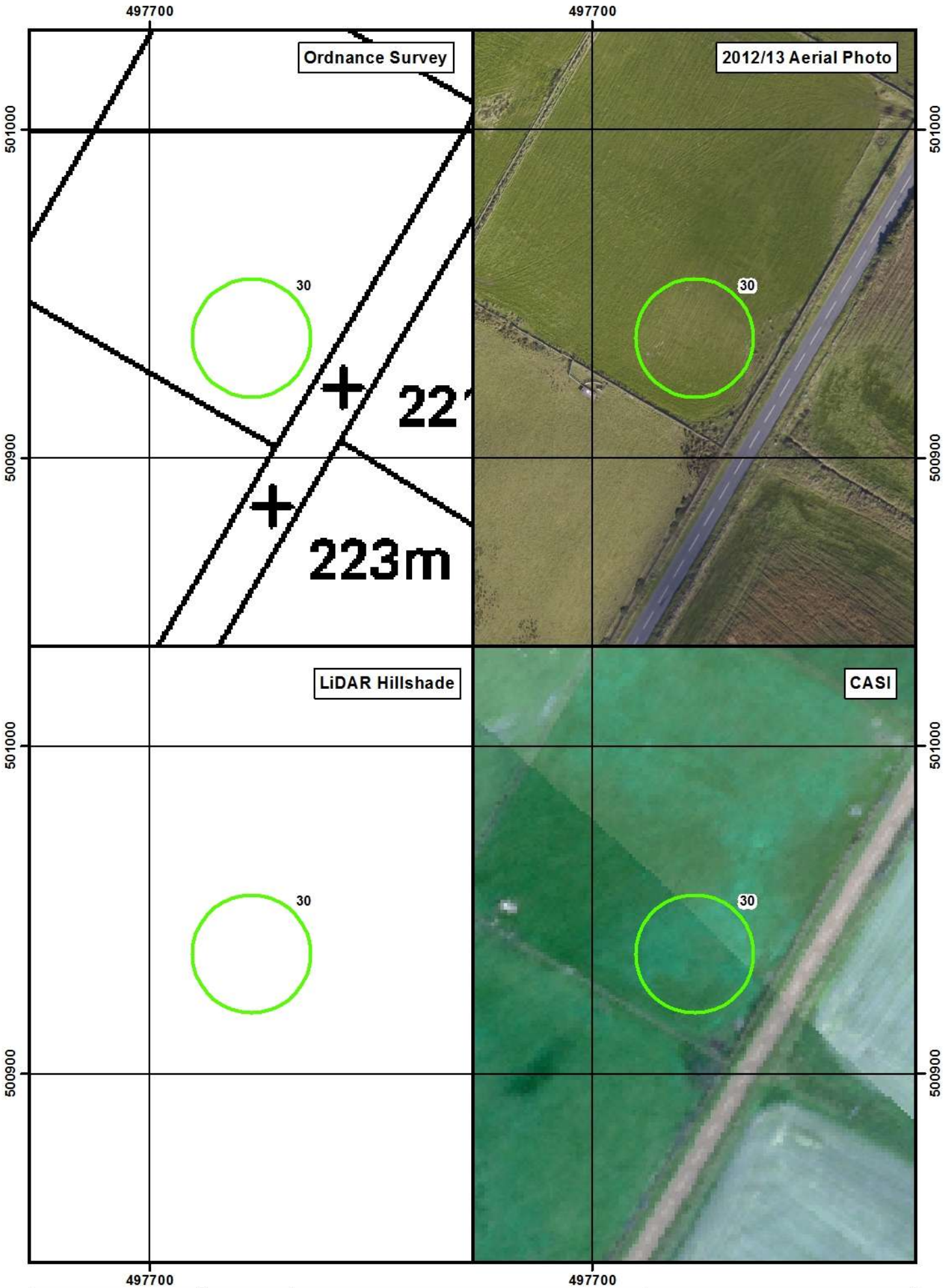
N

0 25 50 75 Metres

Legend

Mapped Anomaly

Scheduled Monument



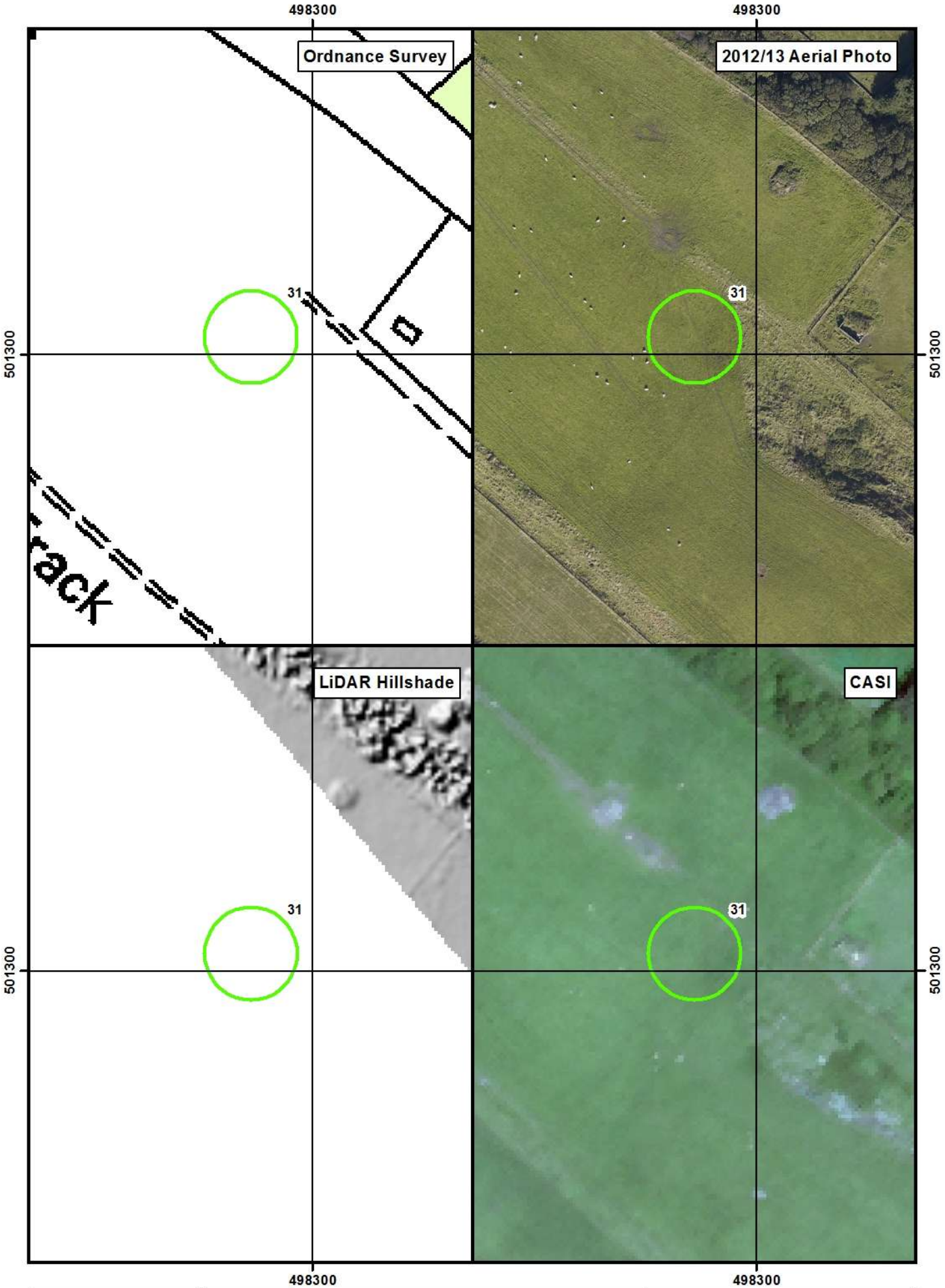
Feature 30: Circular Crop Mark - Possible Barrow

N

0 25 50 75 Metres

Legend

- Mapped Anomaly
- Scheduled Monument



Feature 31: Possible Round Barrow

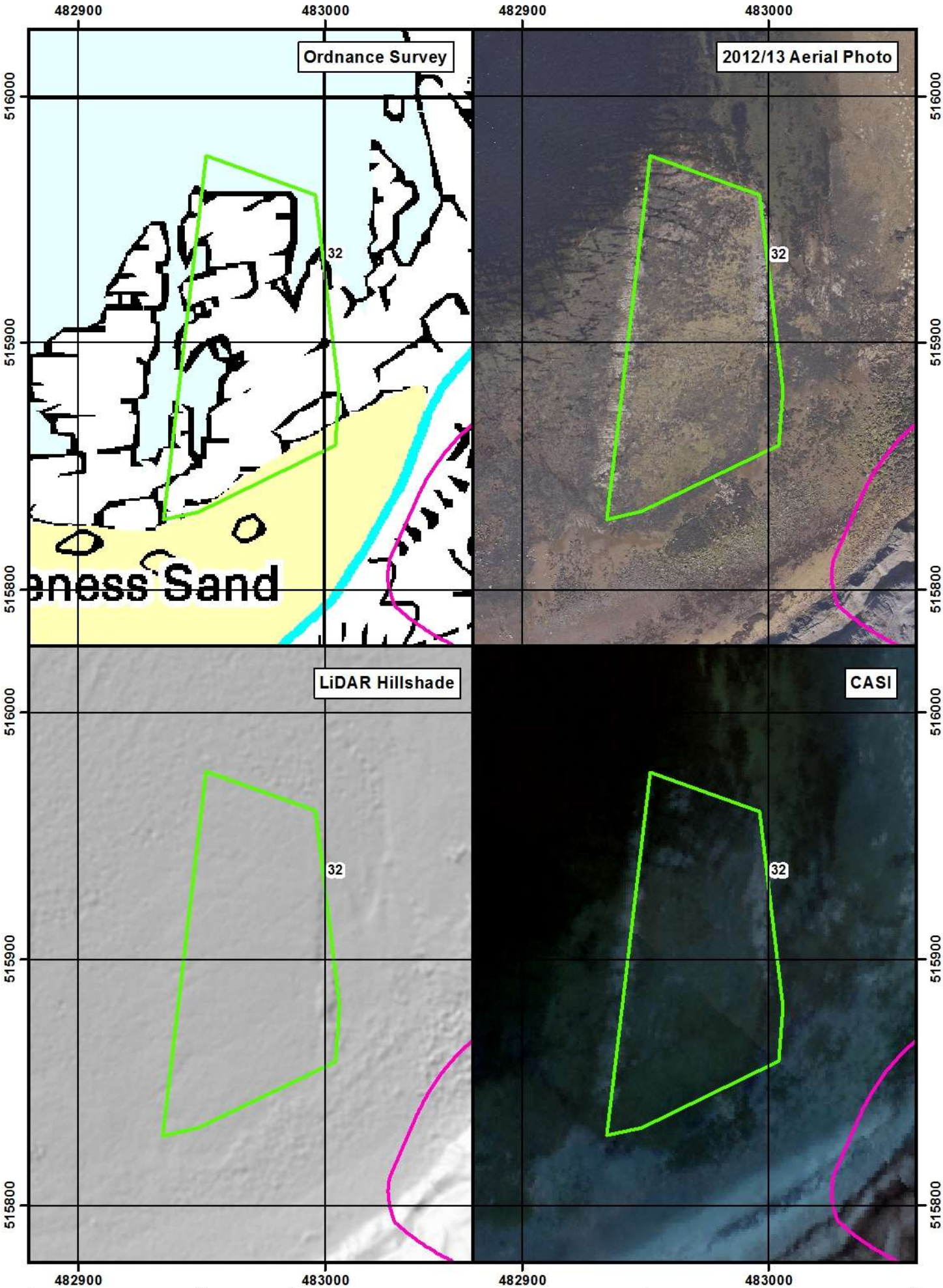
N

0 25 50 75 Metres

Legend

Mapped Anomaly

Scheduled Monument



Feature 32:
Platform Structure
Probably Natural

N

0 25 50 75 100
Metres

Legend

- Mapped Anomaly
- Scheduled Monument