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Geophysical surveys at The Knave and Paviland promontory forts, Gower

Dr Tim Young
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Dr T.P. Young

Abstract

This report details geophysical surveys at two promontory forts in Gower: The Knave (NPRN 301326) and Yellow Top, Paviland (NPRN 301339).

The surveys comprised topographic survey by survey-grade GPS, magnetic gradiometry and resistivity survey.

The two surveys show similar general properties, reflecting their similar topographic and geological settings. Neither survey revealed anomalies certainly identifiable as archaeological features within the defences.

The area within the defences of each site shows only subdued magnetic featuring, dominated by bedrock-controlled lineations. The dominant lineation is that bedding (striking 145-150° at The Knave and 120-135° at Paviland), although at Paviland a lineation directed towards 035° also influenced rockhead topography. The magnetic lineation appears controlled mainly by magnetically susceptible material in rockhead hollows (as suggested by the resistivity survey). It is unclear if the presence of the stronger anomalies of this type represent entirely natural features or whether it is contributed to by the presence of archaeological occupation deposits. The magnetic signature of the extant ramparts is a positive anomaly over their crests and towards their northern (external) faces. The lower part of the outer face, dropping into the adjacent ditch, corresponds to the location of a negative magnetic anomaly. The ditches themselves did not generally show clear magnetic featuring. On both sites, the resistivity survey demonstrated irregular hollows in the rockhead which had previously been related to potential house sites. The surveys shed no further light on whether the hollows had been so used.

Outside the defended area of both sites, the magnetic texture was entirely different, with strong irregular anomalies (> +/-10nT). These anomalies were irregular in the gorse-dominated areas (E side of The Knave), but showed control either by spaced agricultural lineations (NW side of The Knave and NW side of Paviland) or by bedrock (NE side of Paviland). These strong anomalies are likely to be associated with an orange, ferruginous, subsoil observed in these areas. The irregular nature of the anomalies in some areas is possibly controlled by the accumulation of the fine ferruginous material into large anthills. The agricultural lineations are irregularly spaced, with 2.2 to 3.5m spacing, probably indicative of subsoiling.

At The Knave a slight bank extended NNW from the E side of the outer entrance in continuation of the alignment of a flattened area, probably a trackway, between the two defensive lines. This bank showed a marked positive magnetic anomaly. The precise relationship between these features and the inner defensive line was obscured by quarrying. The previously-recognised 'sheepfold' walls crossing the site formed clear topographic features, but were not imaged by either geophysical technique.

There was also a slight bank extending away from the outer entrance at Paviland, but it lies along the agricultural lineation and so was not clearly imaged by the magnetic survey. Several areas in between the two outer defensive lines at Paviland show elevated magnetic gradient, but it is not clear whether these anomalies are due to preservation of archaeological deposits. A small terrace on the W side of the headland at Paviland shows a high magnetic gradient, but it is unclear if this represents a product of magnetically susceptible sediments on the terrace, or is a product of its location on the steep hillside.

Contents

Abstract 1

Methods
- Survey rationale and background 2
- Survey layout 2
- Ground resistivity 2
- Magnetic gradiometery 2

Results: The Knave 2
Interpretation: The Knave 3
Discussion: The Knave 3

Results: Paviland 3
Interpretation: Paviland 3
Discussion: Paviland 4

Conclusions 4

Figure Captions 5
Figures 6

Methods

Survey rationale and background

The survey areas lie on the Gower coast (Figure 1), on open cliff-top land and also, in the case of 'The Knave', adjacent enclosed farmland.

The surveys were conducted between the 28th and 30th April (The Knave) and the 6th and 8th of May 2014 (Paviland). Conditions were good, hot and dry at The Knave, and cool, windy but mainly dry, conditions at Paviland.

According to published British Geological Survey mapping, the sites lie on similar geological horizons, with the coastline mostly cut into the High Tor Limestone Formation, which underlies the Hunts Bay Oolite Formation that forms the more massive main cliffs, which underlies, in turn, the Oxwich Head Limestone Formation a short distance NE of the clifftops. All these units form part of what was formerly known as 'The Carboniferous Limestone' and dip NE (inland) towards the Port Eynon syncline.

In all cases where a high degree of certainty on the presence/absence of archaeological features is required, or a high level of interpretation of those features, then additional investigations, usually including intrusive testing through trial excavation, may be required. Geophysical survey results should not be relied on, on their own, to provide unambiguous interpretations.

Survey layout

Surveys were laid-out using a Trimble 4700/5800 survey-grade RTK GPS system. A temporary base-station, STN1, was created to the SW of Pilton Farm on the first day of the survey. GPS data were logged by the Trimble 4700 receiver for an initial period. Data were converted to RINEX format and were (together with RINEX files from the five closest OS passive net stations) backdated using the *RinexDates* utility to permit baseline processing in *Trimble Geomatics Office*. The data files were then post-processed to give a location for the base-station accurate to within a few millimetres. The corrected location was [243647.07, 186865.27].

The corrected base station was then employed to lay out the survey area at The Knave using locations marked at 'round-number' 20m intervals of National Grid. The system comprised the same Trimble 4700 base-station, with a Trimble 5800 RTK rover. The topographic survey was then conducted using the same combination.

On returning to the area for the Paviland survey, the same base-station location, STN1, was employed for the first day (including the survey of the site edge and the grid layout). In addition a new temporary base-station location, STN2, was surveyed on the edge of the Paviland site. This second station was located at [243720.20, 186095.16]. This base-station was then used for the Trimble 4700 during the second and third days at Paviland, for the topographic survey.

The grid pegs were positioned to within 40mm of the correct location reported by the GPS, which should mean they have a final accuracy to within approximately 50mm of National Grid. Grid locations were marked temporarily by canes.

The grid locations are shown in Figure 2 (The Knave) and Figure 3 (Paviland), which also summarise the topographic survey.

Ground resistivity

The ground resistivity survey was undertaken with a Geoscan RM15 resistivity meter, operating a 'parallel twin electrode' configuration, employing three electrodes with 0.5m probe spacing on a PA5 frame, via an MPX15 multiplexer.

In this configuration, the mobile electrode pairs had a 0.5m spacing (giving the main component of the response from 0.5-0.7m depth), with 0.5m between centres, to give a 0.5m effective traverse interval. Data were collected with 0.5m sample interval (i.e. raw data grid has 0.5 x 0.5m node spacing) on grids mostly walked in a parallel pattern on North-South traverses.

Data were downloaded from the instrument and collated using Geoscan Research's '*Geoplo*t' software. No data processing or grid matching was required.

Data were then exported from *Geoplot* and imported to Golden Software's '*Surfer*'. The data were gridded by kriging to a node-spacing of 0.125m for production of the final, less pixelated, image.

Magnetic gradiometry

Magnetic gradiometry was undertaken with a Bartington Grad 601 Dual fluxgate gradiometer. Data were collected at 0.125m intervals on walked parallel North-South traverses 2m apart (giving effective traverse interval of 1.0m; single density).

Data were downloaded from the instrument, assembled and cleaned using DW Consulting's '*Terrasurveyor Lite v3*' software. The grids were assembled, the data clipped and the destriping function employed for data in which there was an imbalance between the two gradiometers. The data were exported from *Terrasurveyor* and interpolated to a 0.125m node-spacing using Golden Software's *Surfer* package to reduce pixilation where required.

Results: The Knave

The topographic survey line-work is illustrated in Figure 2 and interpreted in Figure 9. The approximate line of the break of slope defining the limits of the monument are depicted by a red line. Areas of exposed rock (or rock immediately below the turf) are outlined in yellow. Areas obscured by the growth of gorse or other undergrowth are outlined in green. Quarries are depicted by magenta lines for both convex and concave breaks of slope. The various breaks of slope associated with the various earthwork features are shown in magenta, cyan and dark blue. Areas of scree are depicted by black lines. Black lines are also employed for modern field boundaries. The black rectangle indicates the location of a large ferrous roller. The modern path is shown in red.

The geophysical survey results are illustrated in figures 3-8.

The magnetic gradiometry data are of good quality and are presented in Figure 3 (as a bitmapped image from

Terrasurveyor of the raw, but destriped, data) and Figures 5-6 (as interpolated data from *Surfer*).

The resistivity data are of very good quality and are presented in Figure 4 (as a raw bitmapped image from *Geoplot*), and Figures 7-8 (as interpolated data from *Surfer*).

Interpretation: The Knave

Within the area enclosed by the defences the magnetic survey revealed no anomalies likely to be of archaeological origin. The data were dominated by low amplitude lineations (dark yellow lines on Figure 17) directed with the bedrock bedding (broadly NW-SE). Around the western end of the inner defences, there were also some NE-SW directed anomalies, probably also of geological origin. Two areas of slight topographical depression showed somewhat elevated magnetic gradient (yellow tone on Figure 17), probably indicating a thicker magnetically susceptible soil, that may include archaeological occupation deposits. The walls/earthworks of the 'sheep-fold' were not imaged by the magnetic survey.

The resistivity survey was mainly controlled by the depth to bedrock, with some minor negative linear anomalies reflecting the bedrock bedding.

The defences were marked by low resistivity and elevated magnetic gradient over the ramparts (with a corresponding negative anomaly on their northern faces), and elevated resistivity in the ditches, but with no clear magnetic anomaly.

Outside the defences there was strong (> +/-10nT) magnetic featuring, dominantly of agricultural origin (in the west), with 2.2m- to 3.5m-spaced anomalies probably indicative of subsoiling (although similar spacing can sometimes be attributable to former lazy-beds). The anomalies were irregular in the gorse-dominated areas to the east of the headland. These strong anomalies are likely to be associated with an orange, ferruginous, subsoil observed in these areas. The irregular nature of the anomalies to the east is possibly controlled by the accumulation of the fine ferruginous material into large anthills.

A slight bank extended NNW from the E side of the outer entrance in continuation of the alignment of a flattened, platform, area, probably a trackway, between the two defensive lines. The external bank showed a marked positive magnetic anomaly. A similar anomaly curves from the bank eastwards to become tangential to the outer fort ditch. This two may be a former bank.

Discussion: The Knave

The interior site had very little soil cover over bedrock, which meant that datasets from both magnetometry and, particularly, resistivity were strongly influenced by the bedrock geology. Some hollows in the bedrock surface corresponded to areas of slightly elevated magnetic susceptibility and hence to areas with possible preservation of thicker soil profiles, perhaps influenced by occupation.

Inland of the fort, disturbance of a ferruginous subsoil has produced strong magnetic anomalies, including one controlled by a low bank oriented parallel to the margin of a platform inside the fort, between the entrances through the ramparts. This feature is an early land boundary – and possibly contemporary with the fort. It may mark the east side of track extending out from entrance to the fort.

Results: Paviland

The topographic survey line-work is illustrated in Figure 10 and interpreted in Figure 17. The approximate line of the break of slope defining the limits of the monument are depicted by a red line; this is not a continuous feature on this site. Areas of exposed rock (or rock immediately below the turf) are outlined in yellow. Areas obscured by the growth of gorse or other undergrowth are outlined in green. Quarries are depicted by magenta lines for both convex and concave breaks of slope. The various breaks of slope associated with the various earthwork and natural features are shown in magenta, cyan, black and dark blue. Areas of scree are depicted by black lines. The modern path is shown in red.

The geophysical survey results are illustrated in figures 11-16.

The magnetic gradiometry data are of reasonable quality, despite the difficulties of maintaining walking pace over steep topography. The magnetic gradiometer data are presented in Figure 11 (as a bitmapped image from *Terrasurveyor* of the raw, but destriped, data) and Figures 13-14 (as the interpolated data from *Surfer*).

The resistivity data are of very good quality, with only minimal striping of the data due to slight imbalance between the electrode pairs. The ground resistivity data are presented in Figure 12 (as a raw bitmapped images from *Geoplot*), and Figure 15-16 (as the interpolated data from *Surfer*).

Interpretation: Paviland

The survey shows the fort to comprise three defensive lines. The outer is formed by a substantial bank and ditch, of which the outer ends curve south. To the east the defences appear to reach the break of slope defining the hilltop (although here disturbed by quarrying), but to the west the outer defences have a gap between their incurved termination and the break of slope, probably marking an entrance. This defensive line was created on the plateau.

To the south, the inner defensive lines make use of a natural topography of alternating upstanding bedrock ribs and intervening rounded topographic lows. The central bank is well formed with a marked ditch to its north, despite probably being based on natural core. This defensive line has an apparent entrance towards its eastern end, but it is unclear if this is original. To the south of this rampart there is a ditch-like hollow, but which may be partially or entirely natural and is not necessarily a feature of the fort itself. There is topographic evidence that this hollow has been closed to the west by an artificial bank along the crest of the slope.

The most southerly bank bounds the southern lip of what is probably a natural gully rather than a ditch. The bank may have had an entrance around its eastern

end. The gully drops rapidly to the west and there is slight topographic evidence for a bank or path along the lower slopes linking the gully with the area to the west of the northern entrance, and it is possible there was access to the southern part of the fort via this external route.

The magnetic survey divides into three sections – a southern part with a rather noisy dataset, possibly indicating the survival of magnetically susceptible soils in small lows on the rockhead surface. The pattern of the associated magnetic anomalies is dominated by bedrock bedding (NW-SE) and more minor SW-NE lineations, possibly bedrock jointing. To the west side of the promontory elevated magnetic gradients were associated with the terrace just below the hilltop. It is unclear whether this indicates substantial magnetic susceptibility for the superficial sediments here, or whether this is a product of its topographic location, with the upstanding hill above it to the SE.

This section shows strong resistivity imaging of the NW-SE Bedding direction, as well as lesser features (jointing?) trending SW-NE.

The central section of the survey shows much lower amplitude magnetic anomalies, reflecting soil in bedding-parallel rockhead hollows and forming the positive rampart features. Towards the north there are several areas of elevated magnetic gradient, hinting at the survival of more magnetically susceptible soils between the frequent minor quarries. In particular there is a zone of elevated magnetic gradient to the rear of the outer rampart immediately east of the outer entrance, which may be of archaeological significance.

As at The Knave, the area external to the fort shows strong magnetic featuring, although here the featuring is both agricultural (NNE-SSW; towards the west) and a mixture of agricultural and geological lineations towards the E (NW-SE). The resistivity survey suggests some large, broad, variation in depth to bedrock in this area, but showed no discrete features.

A prominent, broad positive linear magnetic anomaly runs up the floor of the valley to the west of the outer entrance and continues NE across the plateau. This is probably of geological origin, although an association is possible with the path/track postulated above to pass south to the gully adjacent to the inner rampart.

Discussion: Paviland

The bedrock surface is much more uneven at Paviland (generated by bands of more and less resistant bedrock) than at The Knave, so there is very strong NW-SE geophysical featuring. The inner defences have probably made good use of this natural topography.

Although no discrete archaeological features were noted, areas of elevated magnetic gradient on the terrace immediately NW of the tip of the promontory, associated with bedrock lineations in the central part of the fort and to the rear of the outer rampart, may indicate local survival of magnetically susceptible occupation deposits.

As at the Knave, the plateau inland of the fort showed strong magnetic featuring, again probably due to modern agricultural activity. This again suggests the presence of a disturbed iron-rich subsoil.

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Conclusions

At both sites, the strong control of the geophysical data by the shallow and uneven bedrock geology masked any subtle archaeological featuring within the forts. Both sites also showed evidence for extensive (post-medieval?) shallow quarrying. At both sites, however, the magnetic data allow the recognition of areas with accumulations of more magnetically susceptible deposits that may be of archaeological significance.

At both locations the inland plateau was marked by very strong magnetic featuring, produced probably by disturbance of a strongly magnetically susceptible natural subsoil on the deeply-weathered limestone. The existence of this deposit may have an impact on the application of geophysics to other coastal sites in Gower.

At both sites, the topographic survey revealed that the sides are bounded by ancient (inter-glacial or late glacial) slopes and not by modern sloes/cliffs undergoing active erosion.

Figure Captions

Figure 1. Location of survey areas (base mapping © Crown copyright and database rights 2014 Ordnance Survey).

The Knave

Figure 2. Topographic linework from GPS survey. For key to linework see Figure 9 and text.

Figure 3. Raw (but destriped) magnetic gradiometer data as a bitmapped image from *Terrasurveyor* , greyscale -12nT (black) to +12nT (white).

Figure 4. Raw ground resistivity data as a bitmapped image from *Geoplot*: Greyscale 150 ohm measured resistance (black) to 450 ohm (white).

Figure 5. Interpolated magnetic gradiometer data as an image from *Surfer*, greyscale -8nT (black) to +8nT (white).

Figure 6. Interpolated magnetic gradiometer data as an image from *Surfer*, greyscale -8nT (black) to +8nT (white). Superimposed line-work from GPS topographic survey (as in Figure 2).

Figure 7 Interpolated ground resistivity data as image from *Surfer*, greyscale 150 ohm measured resistance (black) to 450 ohm (white).

Figure 8. Interpolated ground resistivity data as image from *Surfer*, greyscale 150 ohm measured resistance (black) to 450 ohm (white). Superimposed line-work from GPS topographic survey (as in Figure 2).

Figure 9. Summary interpretation.
The approximate line of the break of slope marking the limits of the monument and the cliff-top plateau is marked by the thick dashed line, modern boundaries by thin black lines, and the modern path by the red pecked line. The small black rectangular outline marks a large broken agricultural roller. Areas of gorse are marked in a green tone; most of these were not accessible for geophysical survey. Small quarries are marked in dark grey tone. Areas shown in buff tone have exposed or thinly-covered bedrock. Orange tone indicates areas of scree.

The fort's earthworks are indicated with grey tone for the surviving ramparts (with thin black lines marking prominent breaks of slope in some areas). The outer edges of the associated ditches are shown by a thick black continuous line. The mid grey tone indicates the upstanding features associated with the 'sheep fold'. The dotted black lines indicate the limits of the 'platform' between the entrances of the two ramparts.

Magnetic anomalies: green lines indicate the positive components of an agricultural lineation over an area defined to the west by a negative magnetic anomaly shown in blue. The thin dark yellow lines indicate positive linear anomalies associated with bedrock. The orange lines indicate broad positive linear magnetic anomalies of possible archaeological origin. The yellow tone shows areas of elevated magnetic gradient probably due to thicker soil profiles

Resistivity anomalies (the limit of the resistivity survey is marked by a fine pecked line): pink tone marks areas of high resistivity indicating shallow depths to bedrock. Thin blue lines indicate negative resistivity anomalies, controlled by bedrock.

Yellow Top, Paviland

Figure 10. Topographic linework from GPS survey. For key to linework see Figure 17 and text.

Figure 11. Raw (but destriped) magnetic gradiometer data as a bitmapped image from *Terrasurveyor* , greyscale -12nT (black) to +12nT (white).

Figure 12. Raw ground resistivity data as a bitmapped images from *Geoplot*:
a) external area, greyscale 25 ohm measured resistance (black) to 90 ohm (white).
b) internal area, greyscale 230 ohm measured resistance (black) to 700 ohm (white).

Figure 13. Interpolated magnetic gradiometer data as an image from *Surfer*, greyscale -6nT (black) to +6nT (white).

Figure 14. Interpolated magnetic gradiometer data as an image from *Surfer*, greyscale -6nT (black) to +6nT (white). Superimposed line-work from GPS topographic survey (as in Figure 10).

Figure 15 Interpolated ground resistivity data as image from *Surfer*, colour scales for the two sections of the survey as shown.).

Figure 16. Interpolated ground resistivity data as image from *Surfer*, colour scales for the two sections of the survey as shown.). Superimposed line-work from GPS topographic survey (as in Figure 10).

Figure 17. Summary interpretation.
The approximate line of the break of slope marking the limits of the monument and the cliff-top plateau is marked by the thick dashed line and the modern path by the red pecked line. Areas of gorse are marked in a green tone; most of these were not accessible for geophysical survey. Small quarries are marked in dark grey tone. Areas shown in buff tone have exposed or thinly-covered bedrock. Orange tone indicates areas of scree.

The fort's earthworks are indicated with grey tone for the surviving ramparts. The outer edges of the associated ditches are shown by a thick black continuous line.

Magnetic anomalies: green lines indicate the positive components of an agricultural lineation. The blue lines indicate positive linear anomalies associated either with bedrock or with agricultural activity. The gold area indicates a broad positive linear magnetic anomaly of probable geological origin. Areas of yellow tone indicate areas of elevated magnetic gradient

Resistivity anomalies (the limit of the two areas of resistivity survey are marked by fine pecked lines): pink tone indicates areas of reduced resistivity suggesting thick soil profiles. Thin blue lines indicate negative resistivity anomalies, controlled by bedrock.

Figure 1

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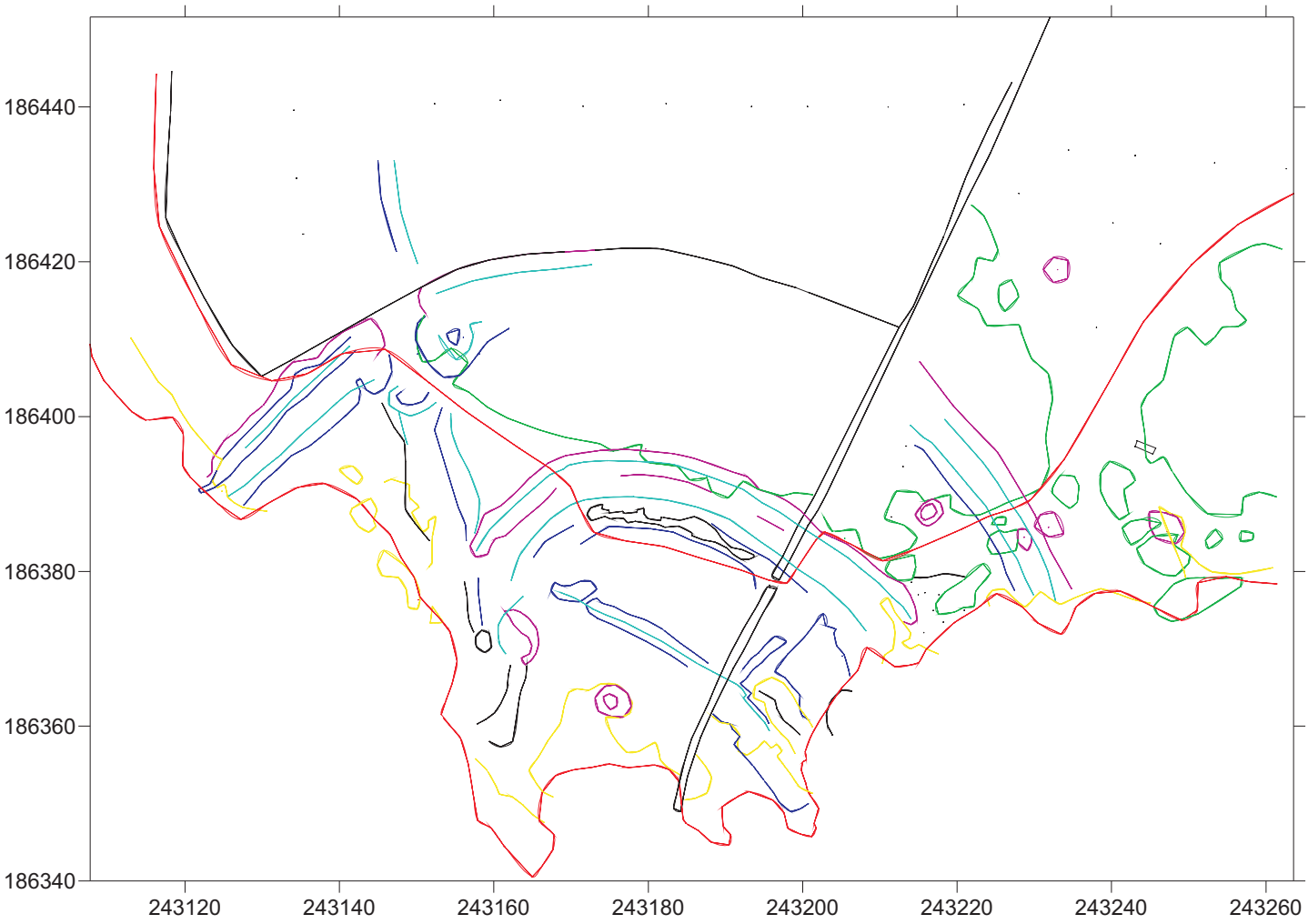
Figure 2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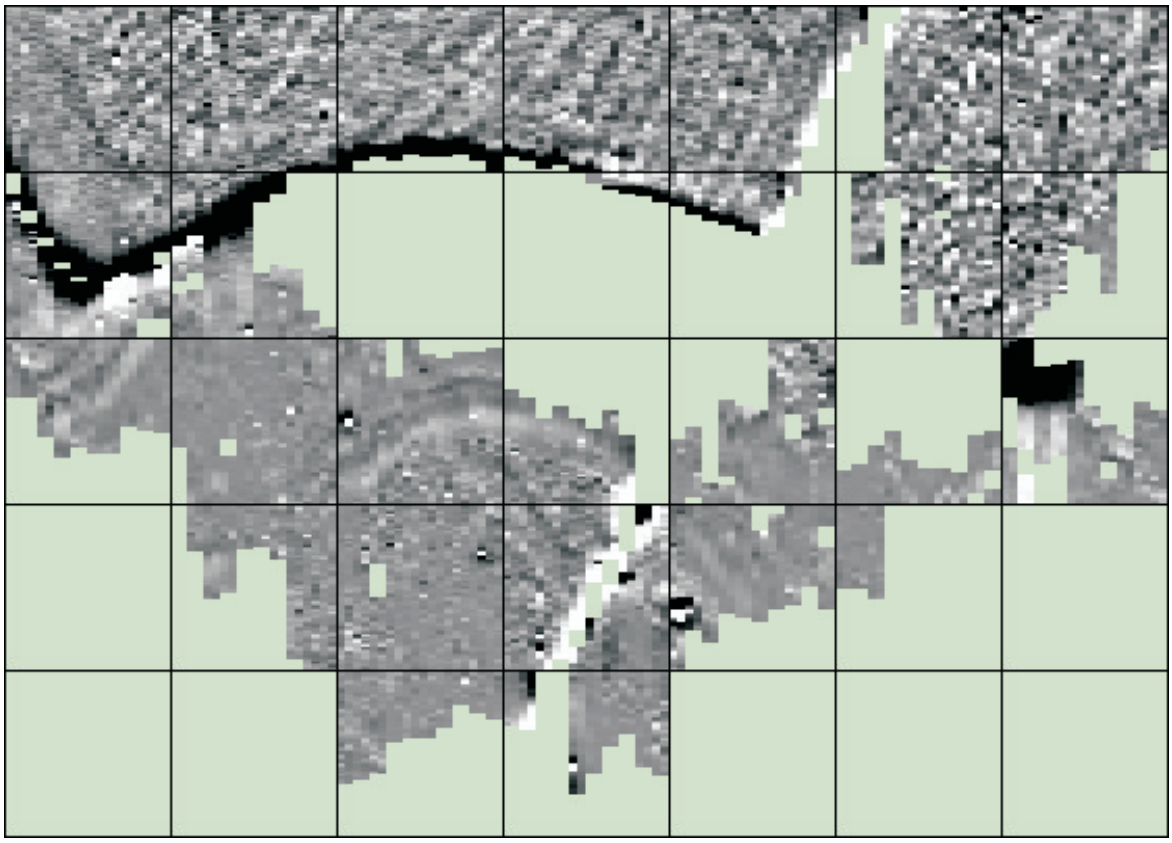

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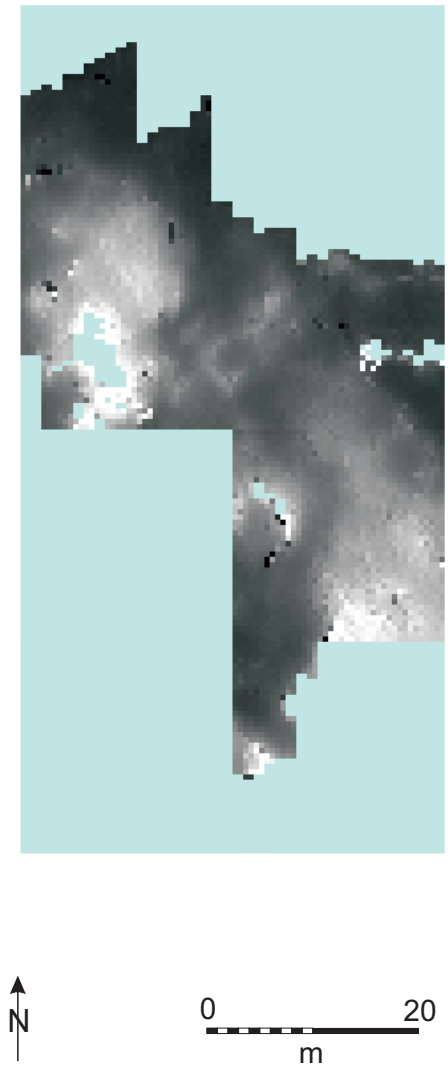

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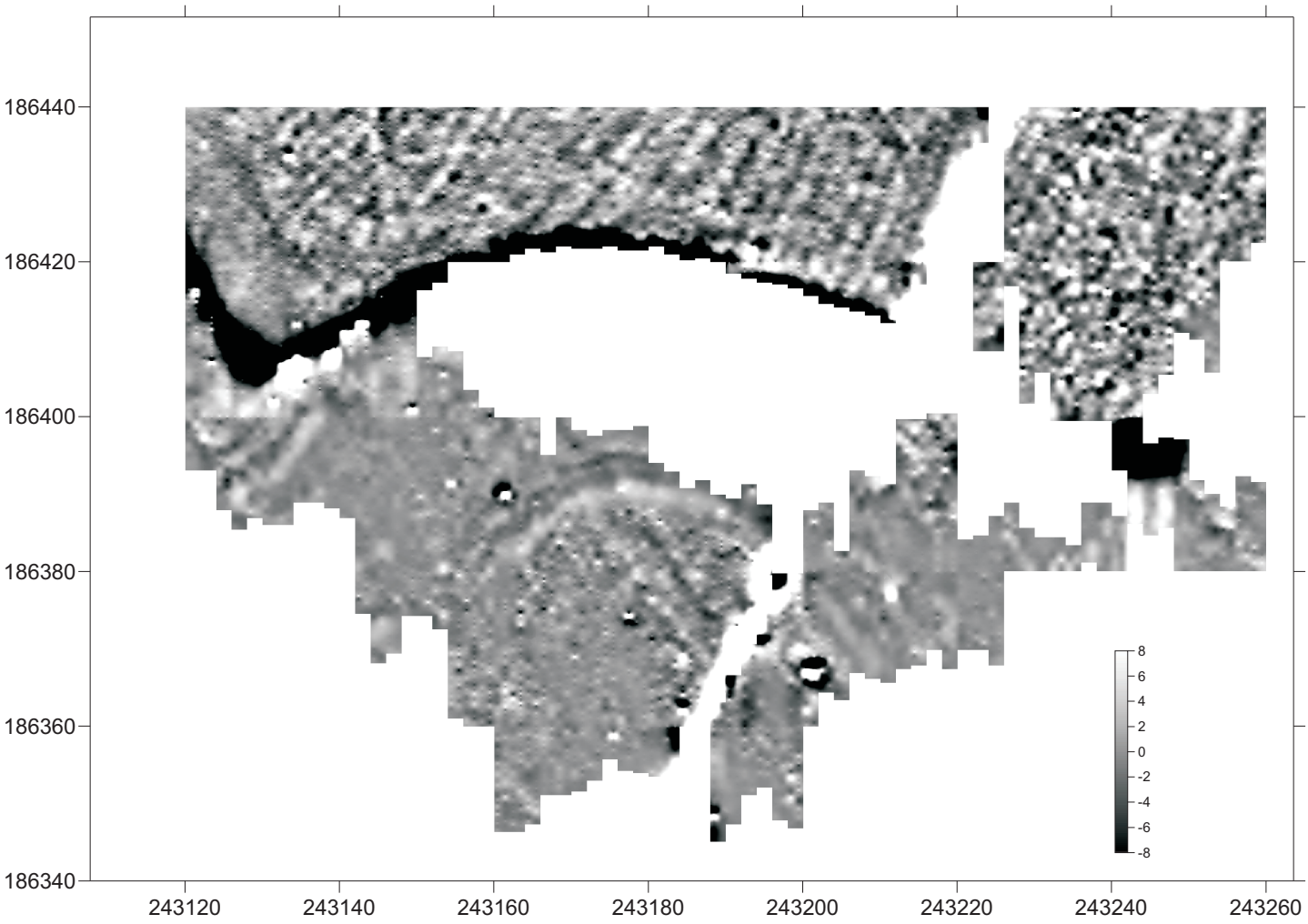
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Figure 6

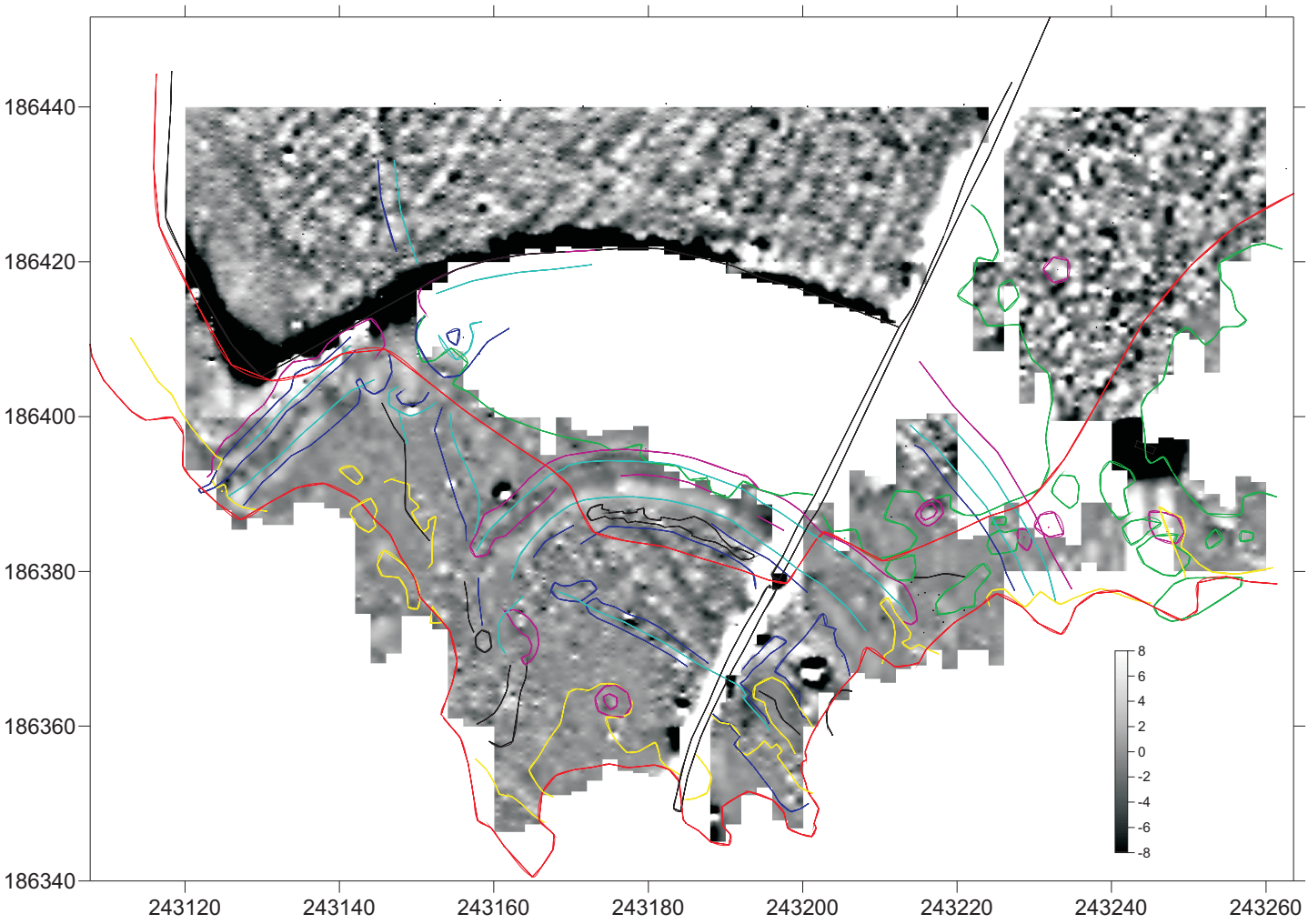
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Figure 7

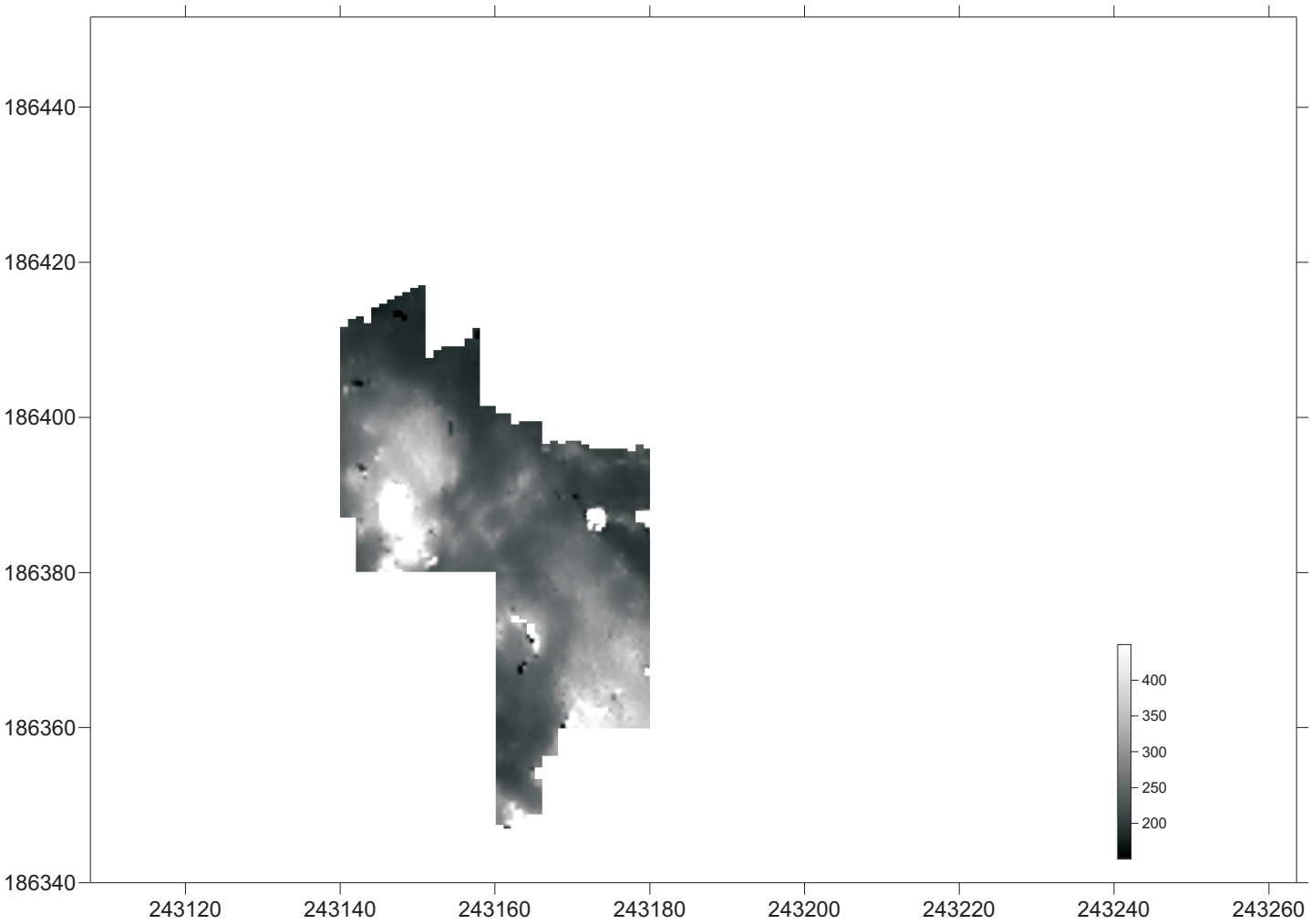
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Figure 8

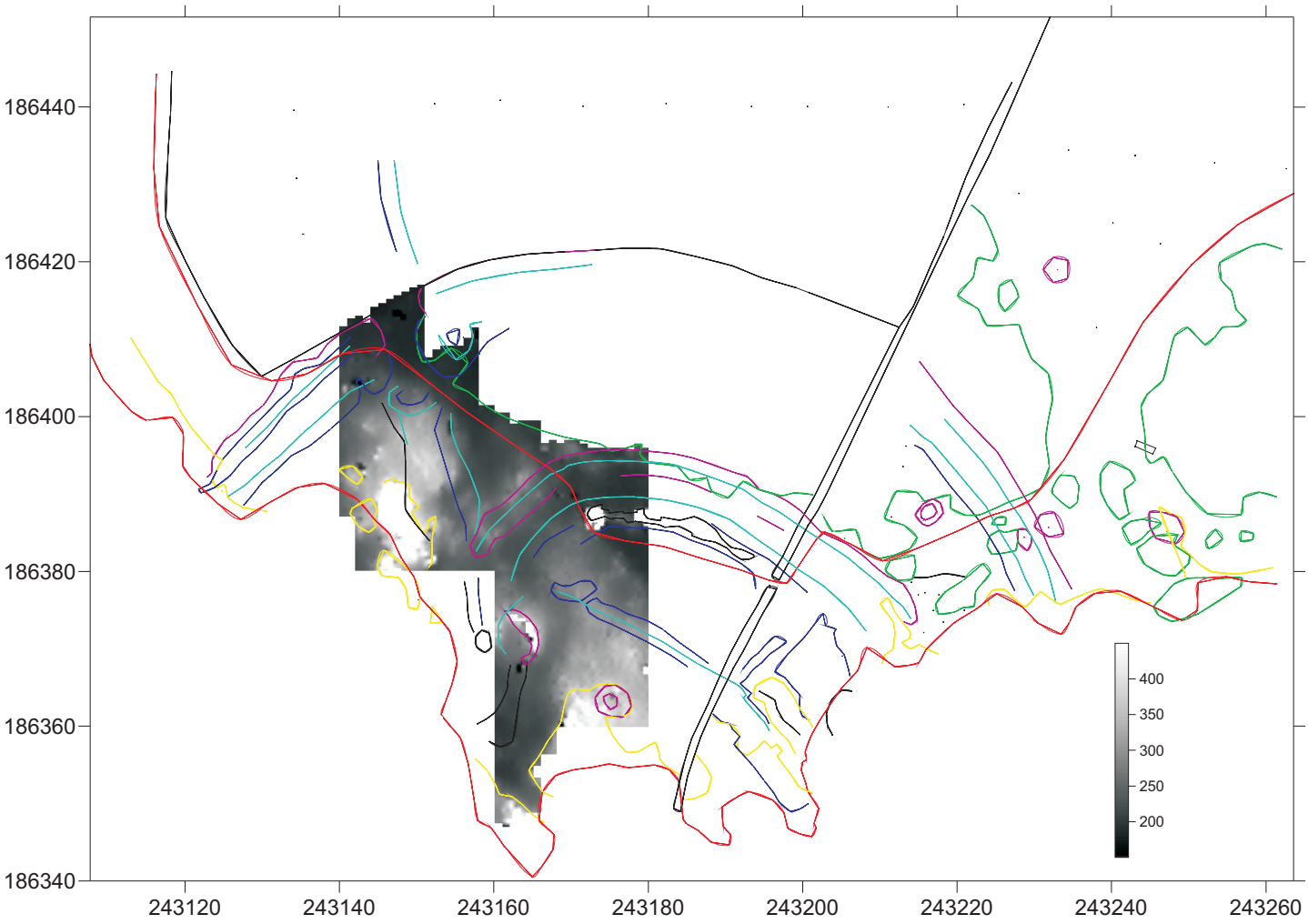
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Figure 9

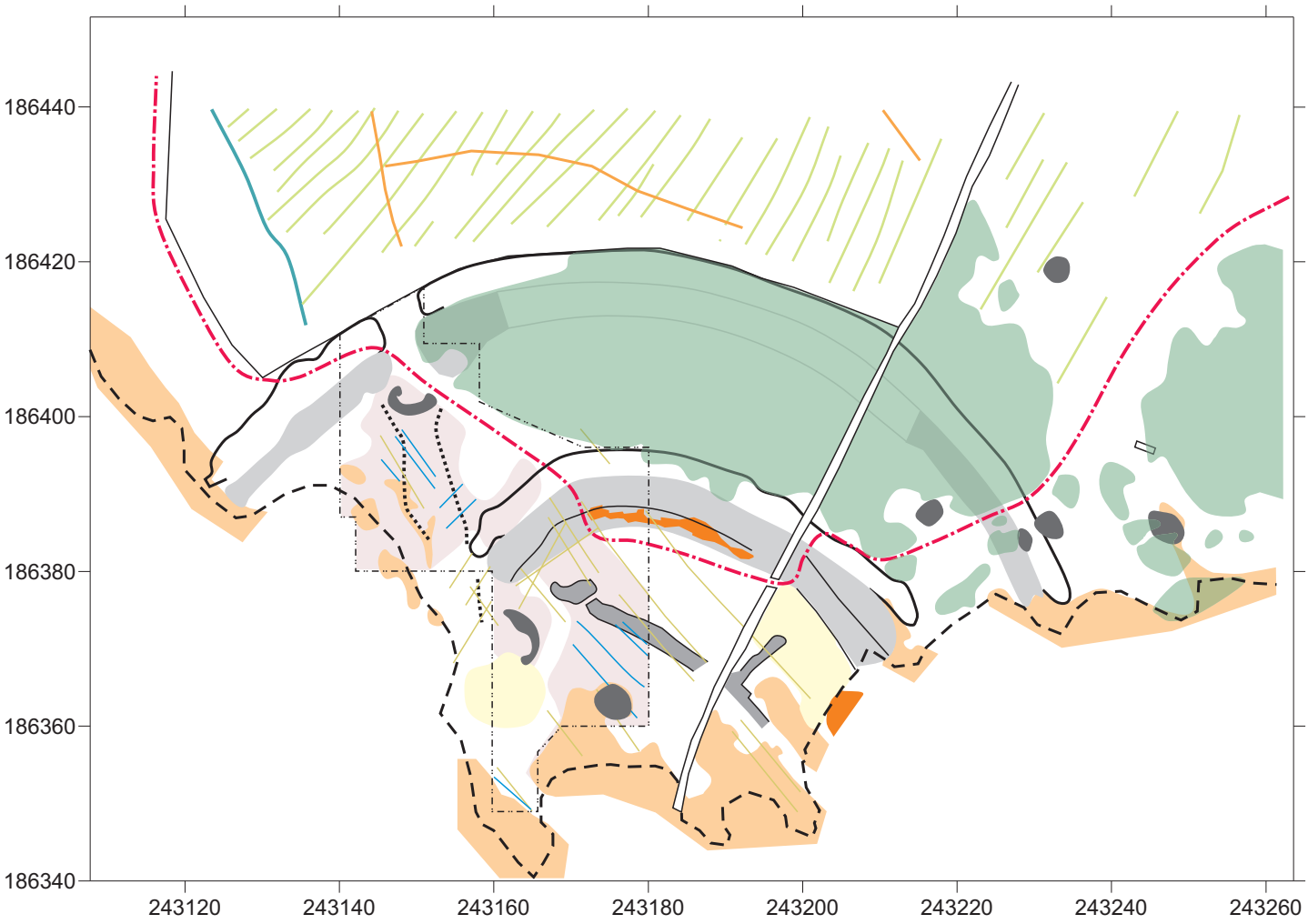
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Figure 10

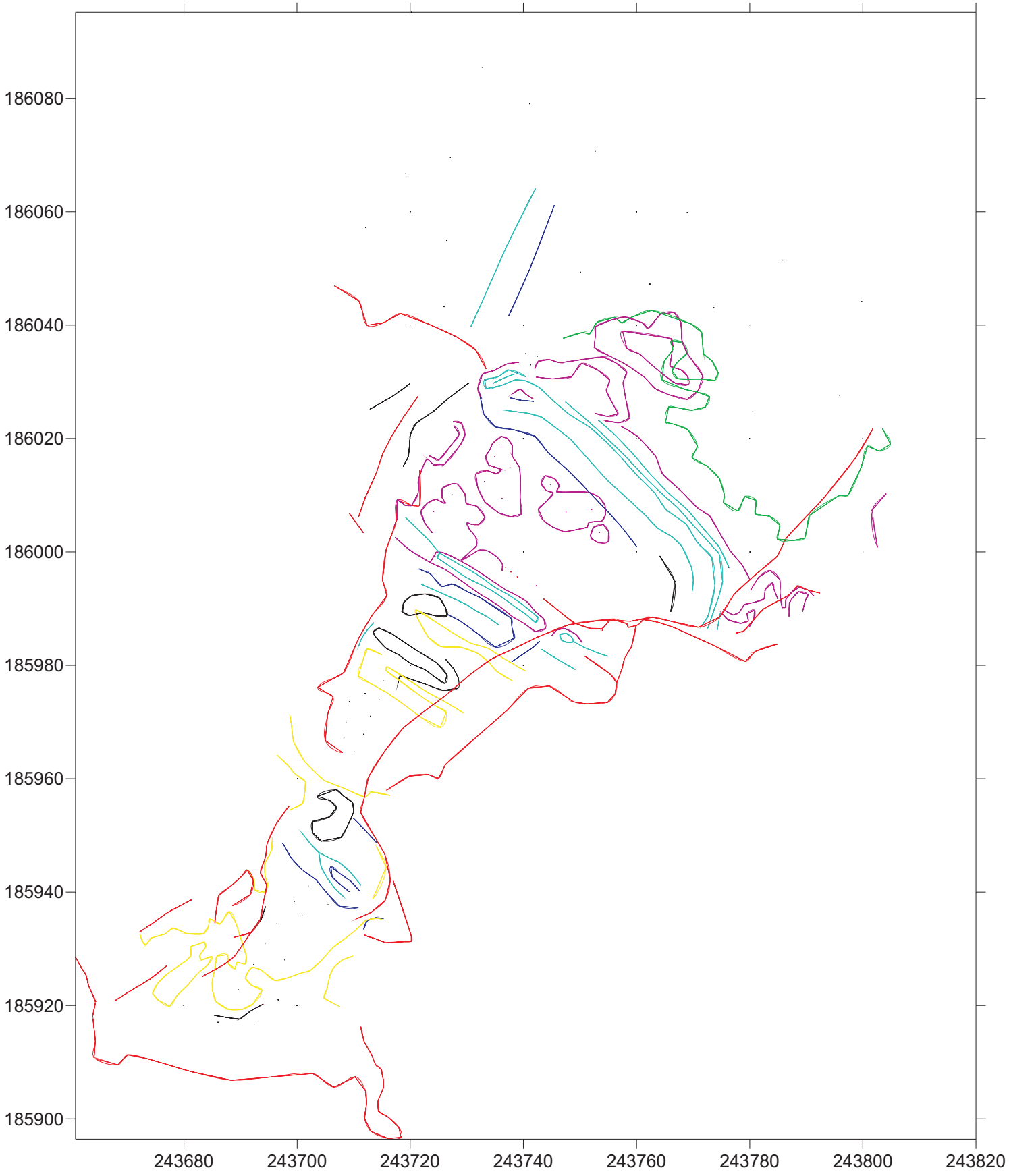
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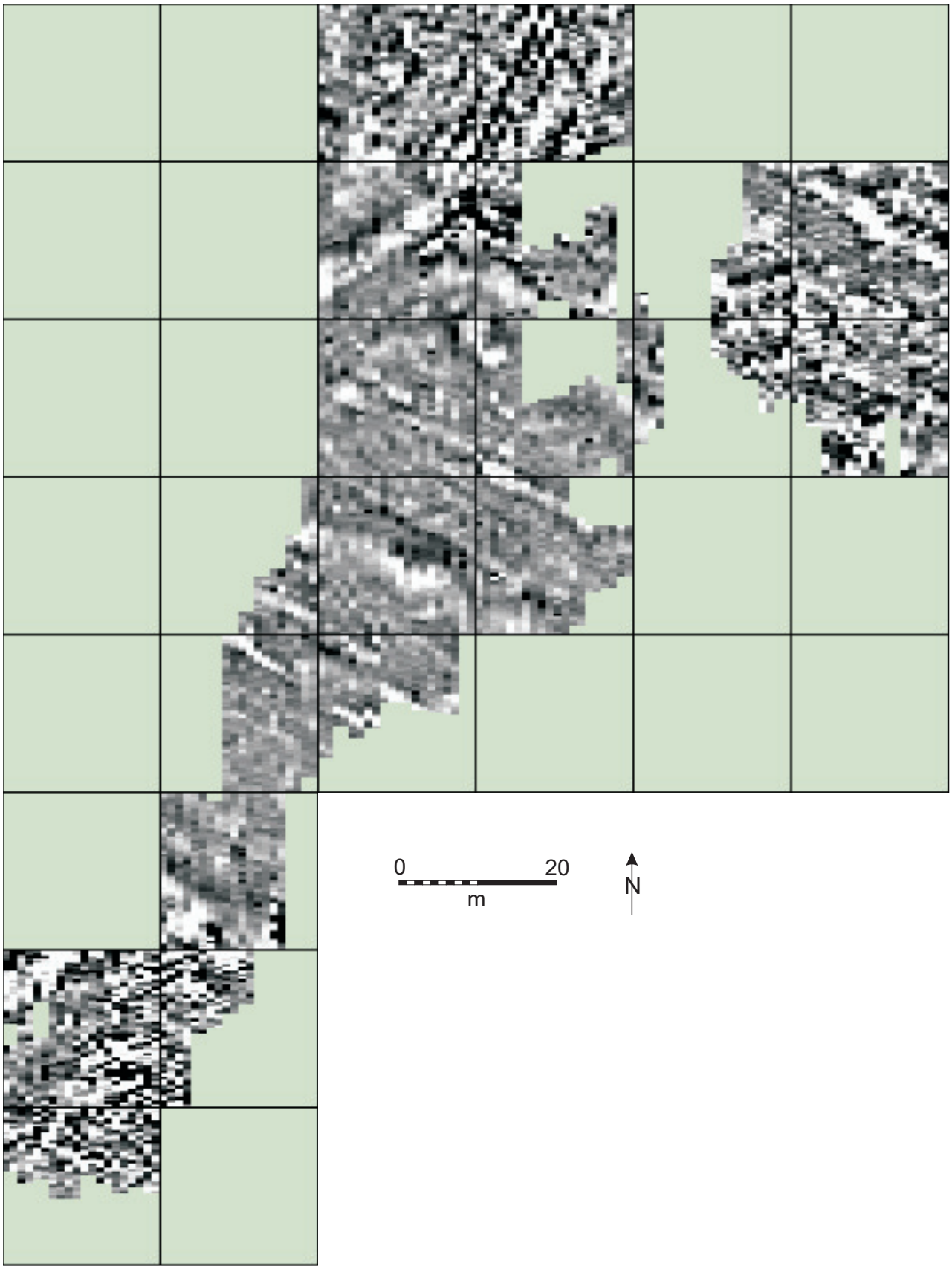
Figure 11



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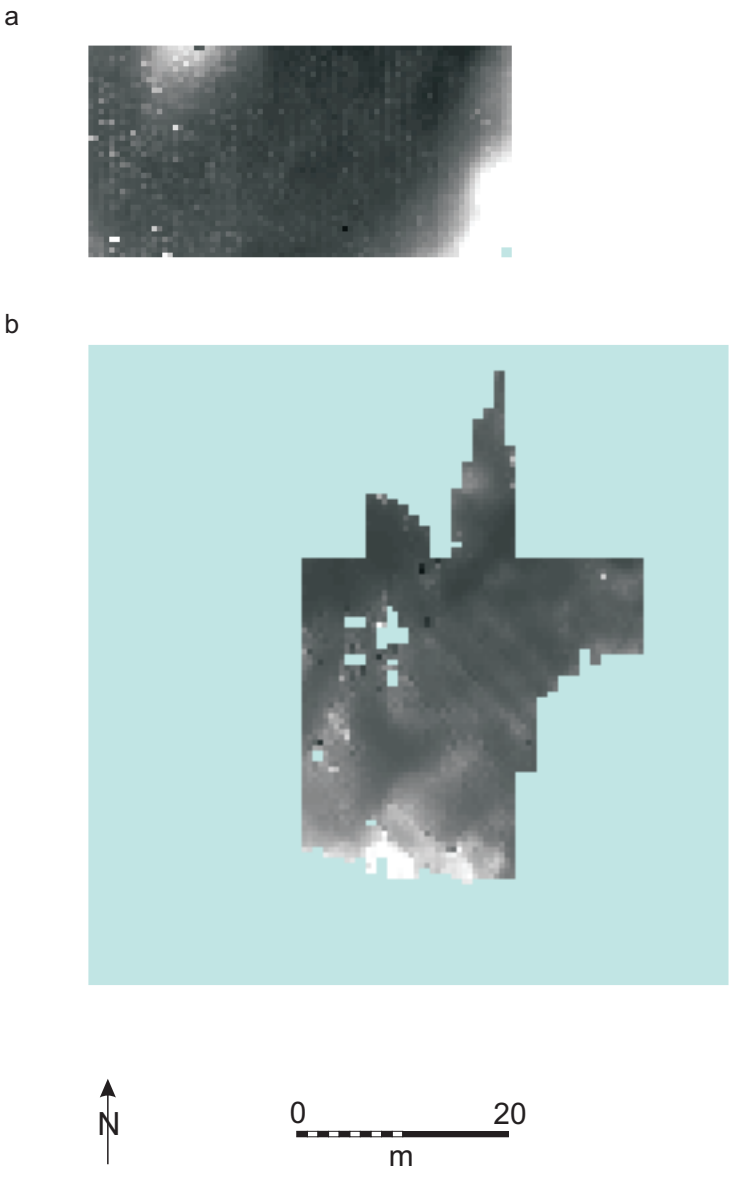

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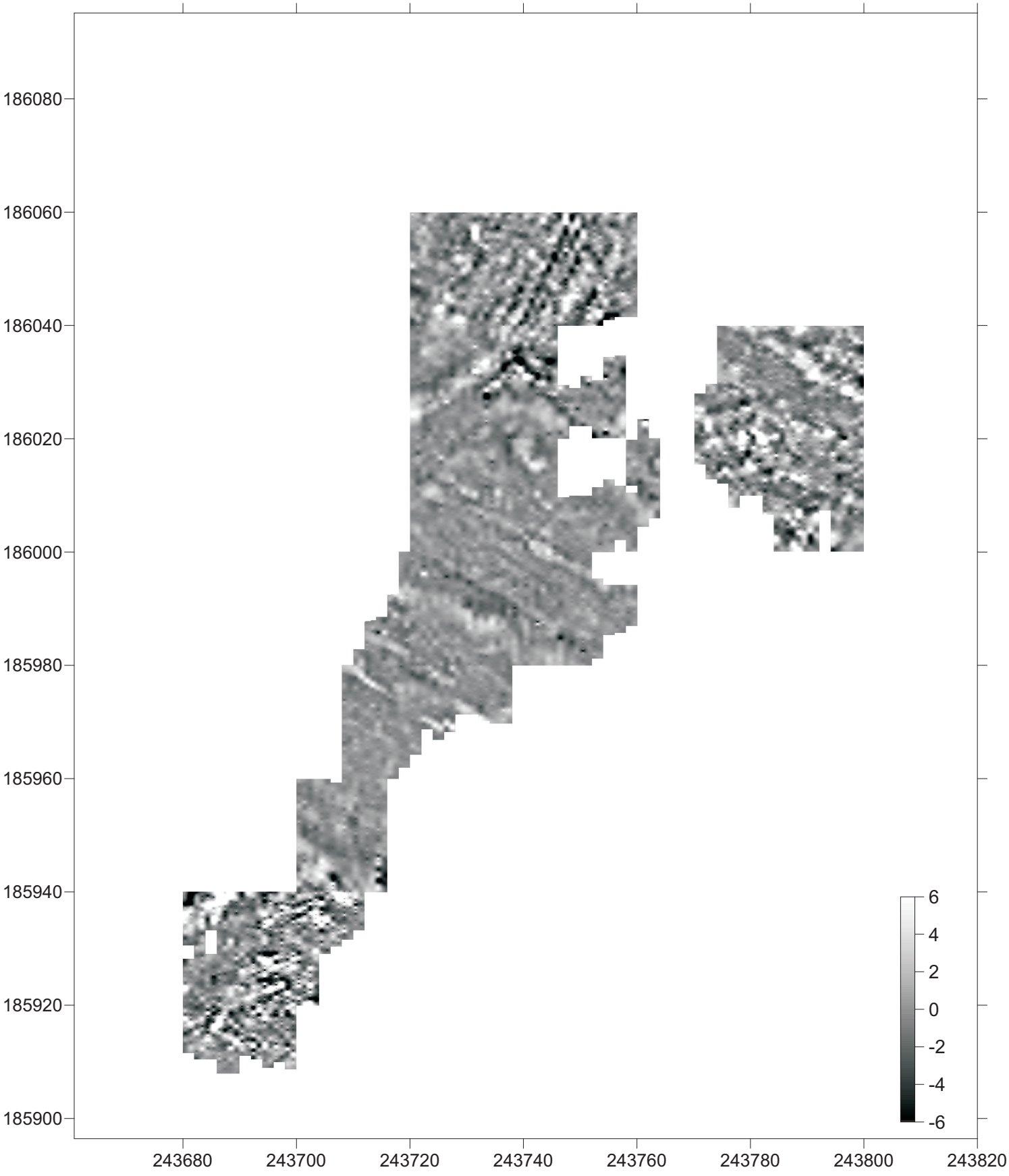
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Figure 14

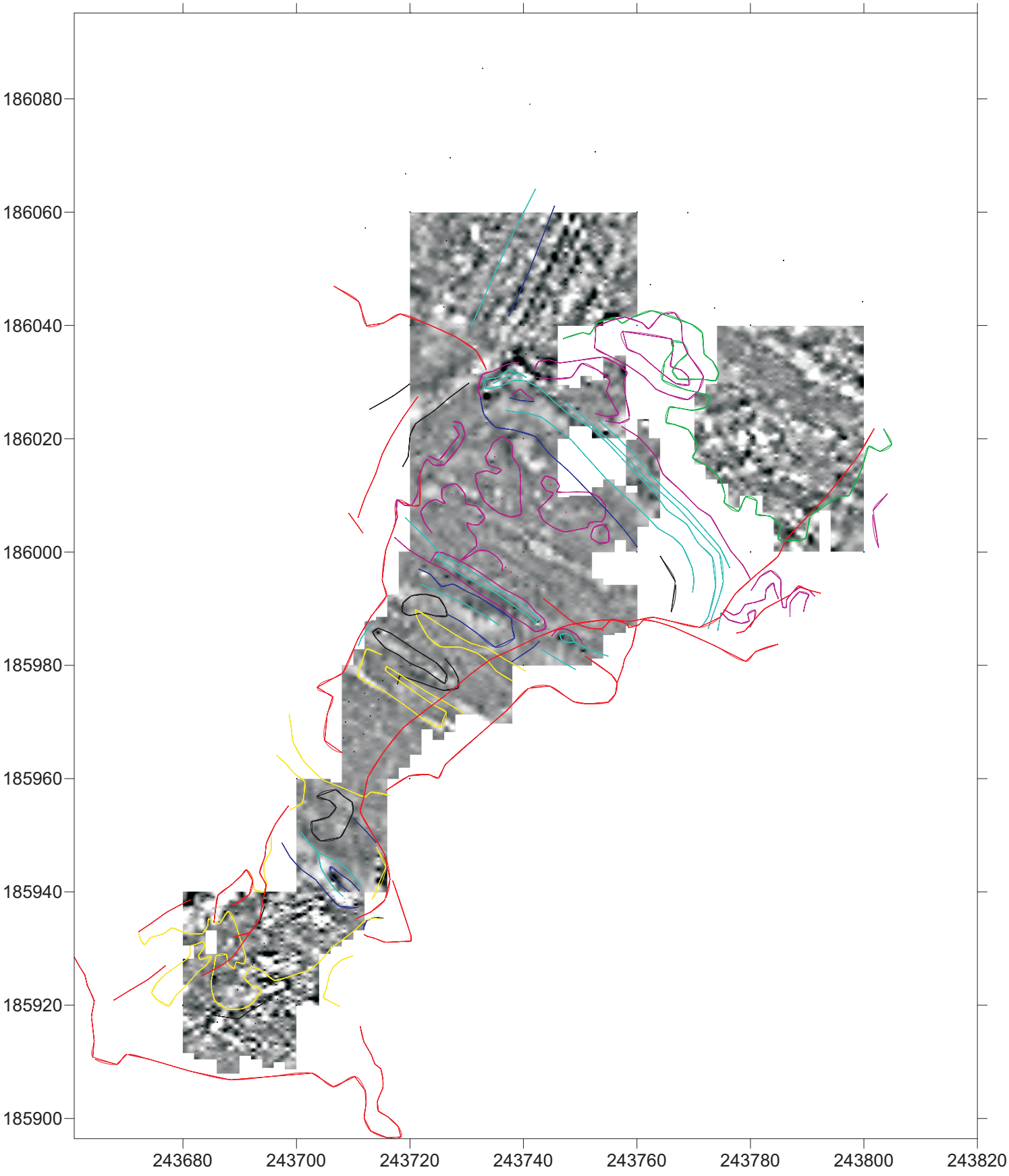
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Figure 15

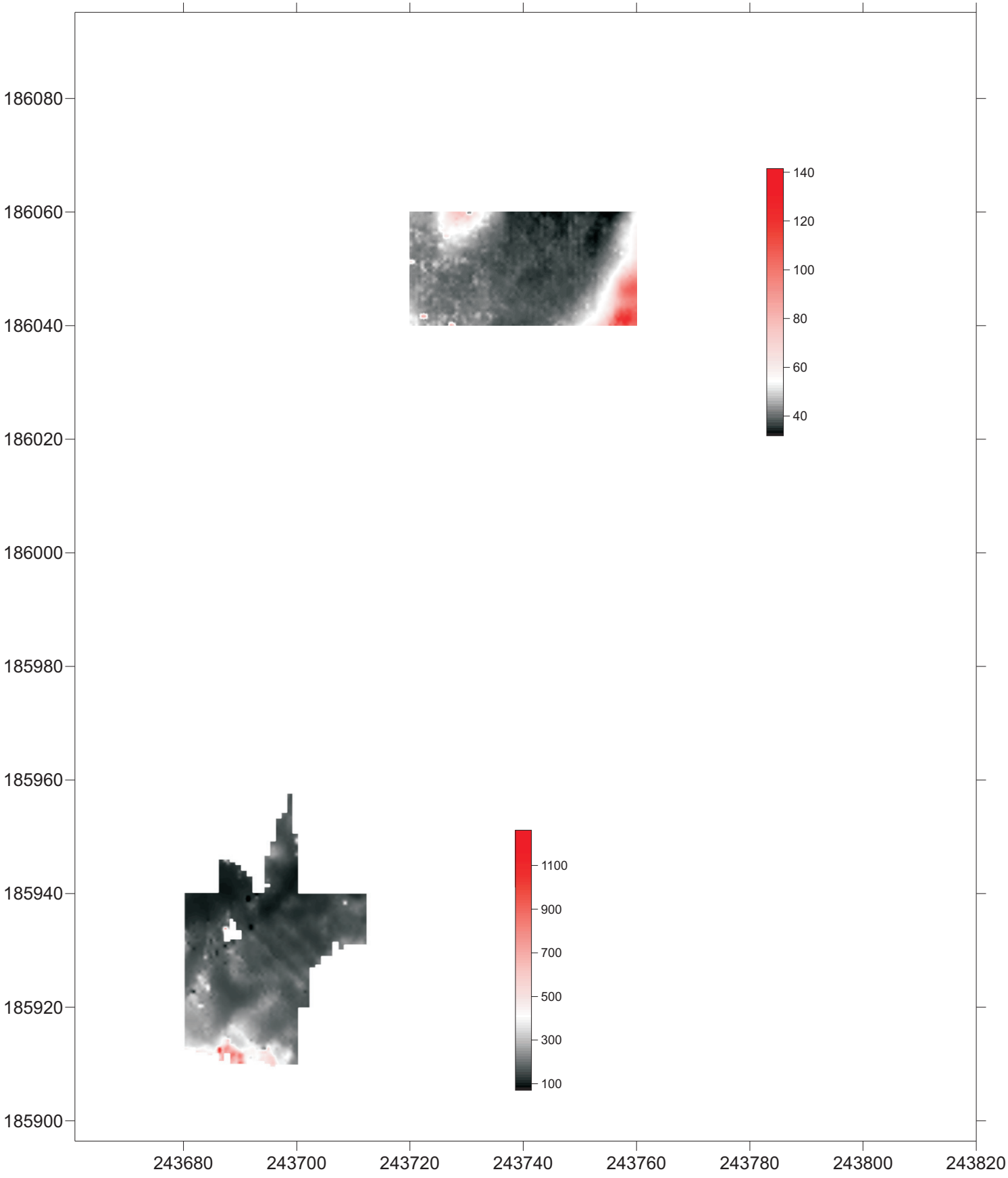
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Figure 16

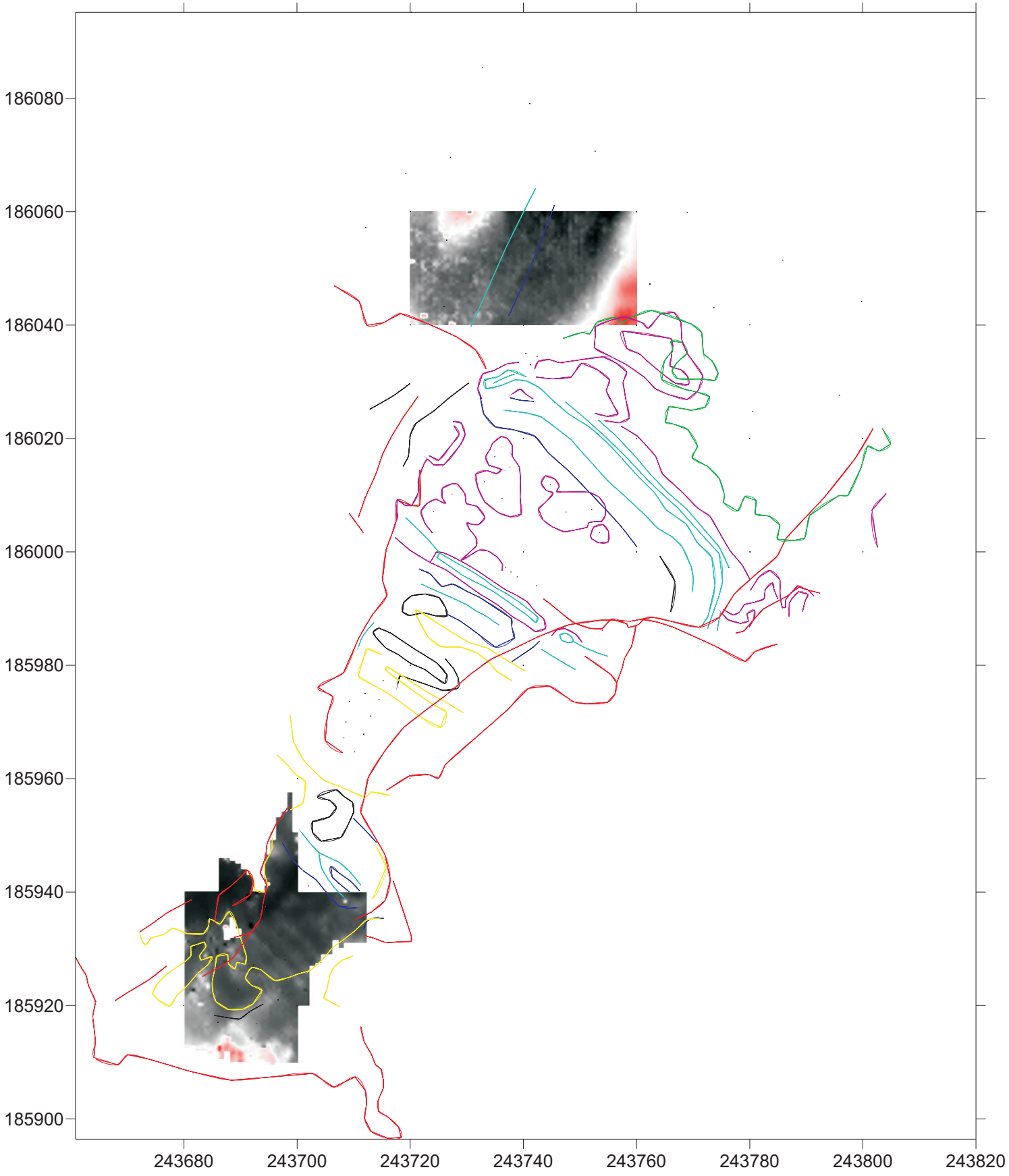
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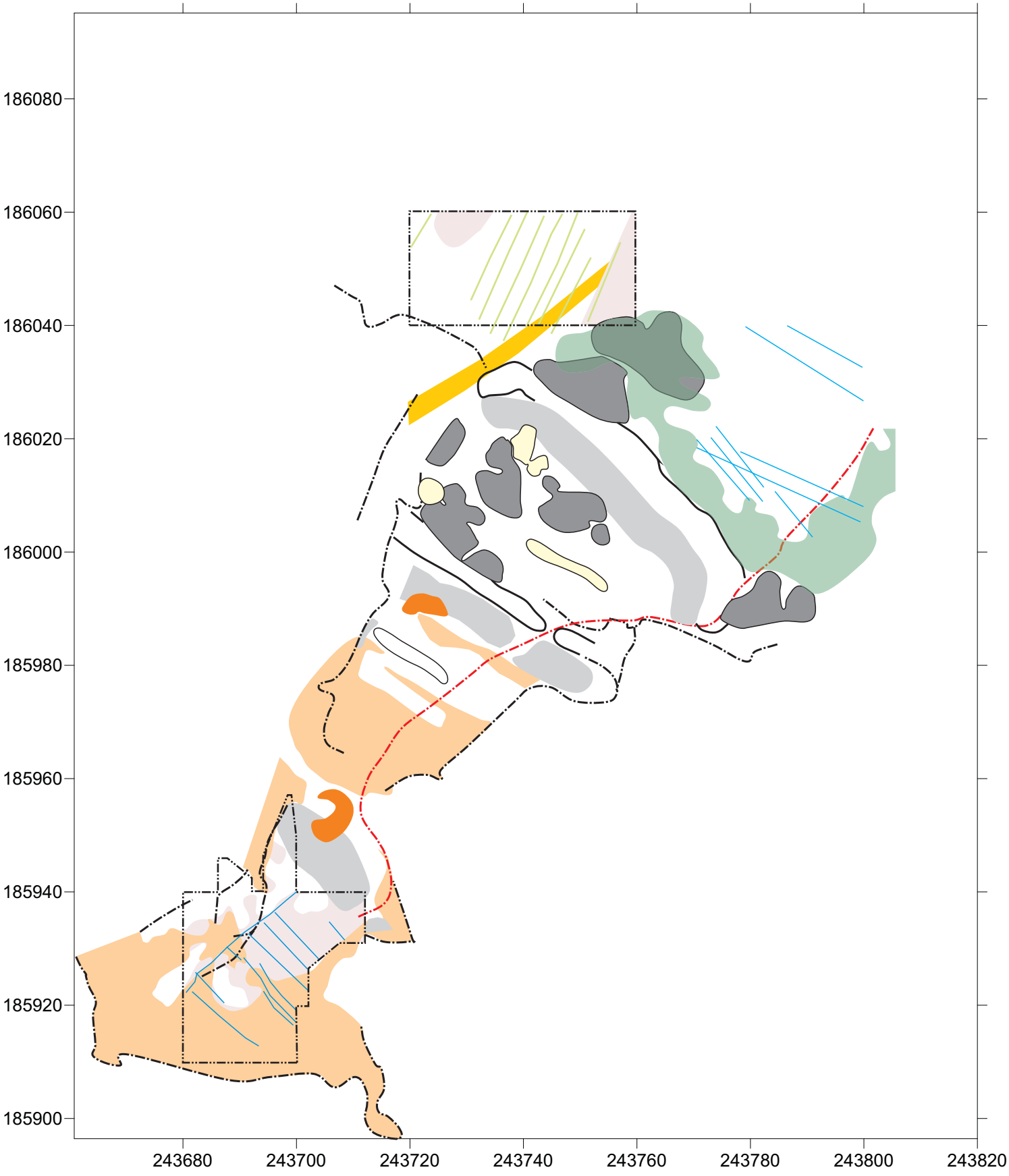
Figure 17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GeoArch

geoarchaeological, archaeometallurgical & geophysical investigations

Unit 6,
Western Industrial Estate,
Caerphilly,
CF83 1BQ

Office:	029 20881431
Mobile:	07802 413704
Fax:	08700 547366
E-Mail:	Tim.Young@GeoArch.co.uk
Web:	www.GeoArch.co.uk