**The deep structure of England from gravity and magnetic profiling**

**John A. Donato[1] & Christopher P. Pullan[2]**

[1] *Merlin Energy Resources Ltd., Newberry House, New Street, Ledbury, Herefordshire, HR8 2EJ*

[2] *CP Exploration, Butts Farm Barn, The Butts, Potterne, Devizes, Wiltshire, SN10 5LR*

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**Abstract**

*As part of the ongoing studies of the Beneath Britain Group in association with the UK Onshore Geophysical Library (UKOGL), twenty-two structural cross-sections have been constructed across northern, central and eastern England. The lines have been built in an attempt to aid an understanding of subsurface geological structure, especially in areas with little or no seismic data coverage and limited deep drilling results. The intention is to define an initial regional network of profiles upon which to build more detailed studies. The profiles are based primarily upon well ties from 227 wells, but also incorporate information derived from seismic interpretations and from published depth structure maps. Density and susceptibility values, based upon published information and upon an evaluation of well logs, have been allocated to individual stratigraphic units within the twenty-two 2.5D gravity and magnetic model profiles. The various models have been used to remove the combined gravity effect of the younger, better-known, geological structure, revealing residual anomaly contributions to the gravity and magnetic fields from deeper geological features. Of the thirty-four gravity anomalies identified, twenty are significant residual anomalies and range in amplitude from 4 to 25mGal with an average of approximately 12mGal. Most of the features have been recognised previously but some are new. The residual anomalies are interpreted in terms of granitic plutons or Paleozoic basins with two remaining anomalies of uncertain origin. The profiles and models do not provide unique solutions but can help to constrain geological interpretations, especially when combined with other datasets. Work to set the identified gravity and magnetic anomalies within a regional geological context is currently underway and will be described in future publications as part of the ongoing research of the Beneath Britain/UKOGL Group.*

## Introduction

A series of twenty-two depth cross-sections have been constructed extending across northern, central and eastern England. The profiles have been built in an attempt to assist an understanding of deep geological structure, particularly for those areas with a lack of reflection seismic data and sparse deep-drilling well results. The profiles are based upon an integration of stratigraphic tops, derived from 227 wells and boreholes, combined with published structure maps together with seismic line interpretations. The cross-sections have been converted to a series of simplified 2.5D model profiles with assumed density and susceptibility values ascribed to the main stratigraphic units. The density model parameters are based upon an evaluation of density logs run in 133 wells together with published data. Magnetic susceptibility values are derived from published information. The gravity modelling was undertaken in order to 'strip off' the gravity effect of the known, or better understood, shallower geological structure in order to extract a residual gravity field thought to be due to deeper and less understood geological features. The method adopted for modelling all profiles was as follows:- (i) to model a 'shallow' cross-section, usually of the Carboniferous and younger sediments, based upon well tops, seismic control and published maps, (ii) to subtract the effect of this mapped shallow geology from the observed profiles, producing gravity and magnetic residual anomalies, (iii) to model the residual anomalies with geological speculations regarding the deeper less-known section using the often-limited geological data. In this way, the effect of the shallow geology was 'stripped away' prior to introducing any additional speculative features. Gravity modelling requires significant assumptions regarding the background regional field. For the network of intersecting profiles described here, a consistent regional background field has been adopted assuming a background

basement density of 2.72 kg/m$^3$. Gravity and magnetic modelling do not provide unique solutions, but it is hoped that the results help to constrain possible geological structural models. The intention has been to create a network of intersecting, simple profiles, providing an approximate fit between observed and calculated potential field values and forming a basis for further, more detailed, studies.

## Data Sources

The primary data sources include well data, seismic structural mapping, gravity data, magnetic data, and density and magnetic susceptibility data.

Well data were derived mainly from the UKOGL (UK Onshore Geophysical Library) well database. Stratigraphic tops, from surface to TD, were interpreted in 227 wells. The stratigraphic succession of the Mesozoic section in the wells is based on the framework created by the British Geological Survey (BGS) and as detailed in their various published Subsurface Memoirs, Sheet Memoirs and Regional Guides. For the purpose of the present study, the Carboniferous section, below the Variscan unconformity, has been subdivided into the Upper Carboniferous Coal Measures and Namurian intervals, and the Lower Carboniferous Carbonates and Shales, and can be generally differentiated with confidence based on the intervals' lithology. The Devonian section below is more difficult to identify due to the general paucity of palaeontological control and the general lack of characteristic lithological features. To the west in Wales, a major unconformity has been recognised at the base of the Upper Devonian, but in Eastern England this major unconformity could be of latest Silurian to early Devonian age. These are together termed the "Acadian" Unconformity in this paper. The Lower Paleozoic interval has been subdivided into three tectonic-stratigraphic intervals following the scheme suggested by Woodcock (Woodcock, 1991). The youngest interval is a Late Ordovician to Lower Devonian section which is truncated by the Acadian Unconformity. The second sequence of Ordovician age lies between the Shelveian and Penobscottian unconformities. The oldest section, lying on Precambrian Basement, is of Lower Cambrian-Early Ordovician (Tremadocian) age and is truncated by the Early Ordovician Penobscottian unconformity. Identification of the Lower Paleozoic section is hampered by the limited data available. It is particularly difficult to age-date the deepest sections penetrated in wells in the Fenland area. In many wells, no electric logs were run and so there is a reliance on few samples, often only cuttings with no core data, and many of the lithological descriptions are extremely sparse and poor. Furthermore, the amount of Lower Paleozoic section penetrated in the wells is limited, with few palaeontological dates. Many of the samples are from intervals that were deformed and have undergone varying degrees of metamorphism, so that much of their original character has been modified or lost.

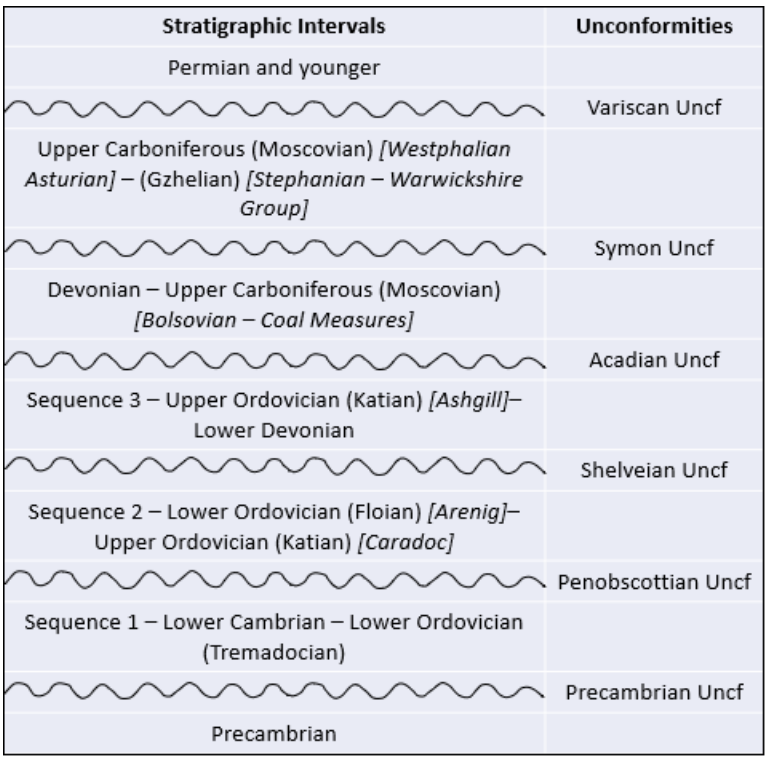



*Figure 1 Stratigraphic Summary. Local UK stratigraphic terms are shown in square brackets*

A listing of all well data used is provided for each profile. This includes well name, location in British National Grid (BNG) coordinates, distance along the profile (km), total depth (m) and interpreted bottom-hole formation. The wells were grouped to form a series of twenty-two, approximately linear, cross-sections (Figure 2(a)). An attempt was made to keep the profiles as straight as possible, but some 'dog-legs' were inevitable. The length of the profiles varies between 89 and 308 km and the number of wells used per cross-section ranges between 6 and 24. Constructed cross-sections honoured the well ties, and seismic mapping, where available, was utilised to infill the structural form between the well control points. In cases of disagreement between well tops and seismic mapping, the well data were given precedence.

Published mapping was derived mainly from the '*The Atlas of Onshore Sedimentary Basins in England and Wales*' (Whittaker, 1985). The Atlas provides a series of twelve depth-converted structure maps at 1:1,500,000 scale with stratigraphic horizons ranging between the deepest at 'Top Variscan Basement' to the shallowest at 'Top Chalk'. The data used to construct the maps within the Atlas include surface geological information, subsurface well data derived from approximately 3,000 wells and boreholes, and seismic reflection profiles acquired mainly by companies prospecting for hydrocarbons. Depth contours for key horizons were digitised and gridded. Horizon cross-sections were then extracted from the various depth grids along the line of each profile, and these were used to aid the construction of the models. Unfortunately, the BGS Atlas (Whittaker, 1985) does not provide interpretation of any pre-Permian structure, such as Carboniferous horizons. The modelled Carboniferous and older structure of northern and central England relies heavily on the BGS Subsurface Memoirs: 'Structure and evolution of the East Midlands region of the Pennine Basin' (Pharaoh, et al., 2011), 'Structure and evolution of the Craven Basin and adjacent areas' (Kirby, et al., 2000) and 'Structure and evolution of the south-west Pennine basin & adjacent areas' (Smith, et al., 2005).

Published and unpublished seismic interpretations have been undertaken by M Butler covering wide areas of Central England, notably over and around the Worcester Graben and over the Midlands Microcraton (Butler, 2018). In this paper we refer to the Midlands Platform as the part of the Midlands Microcraton that lies north of the Mesozoic Basins of Southern England. These interpretations were merged with the BGS mapping to assist profile construction. Intersection points between the profiles and the regional seismic line interpretations of Butler and Jamieson (2013) were also examined and incorporated.

Observed gravity and magnetic anomaly data were obtained from BGS published potential field maps, 1:1 000 000 UTM Series; the gravity field from Chacksfield & Edwards (2006) and the magnetic field from Chacksfield, et al. (2006). Assumed layer density values were estimated following an assessment of densities recorded in density logs run in 133 wells located across England. A full summary of these results will be presented in a future publication by the authors. In addition, published surface and subsurface density values were incorporated using, in particular, the comprehensive density review available on the BGS CD-ROM 'Regional Geophysics of South-east England' (Busby, et al., 2006). Assumed susceptibility values were based upon published values but relied heavily on the synthesis of published susceptibility results also provided by Busby, et. al. (2006).

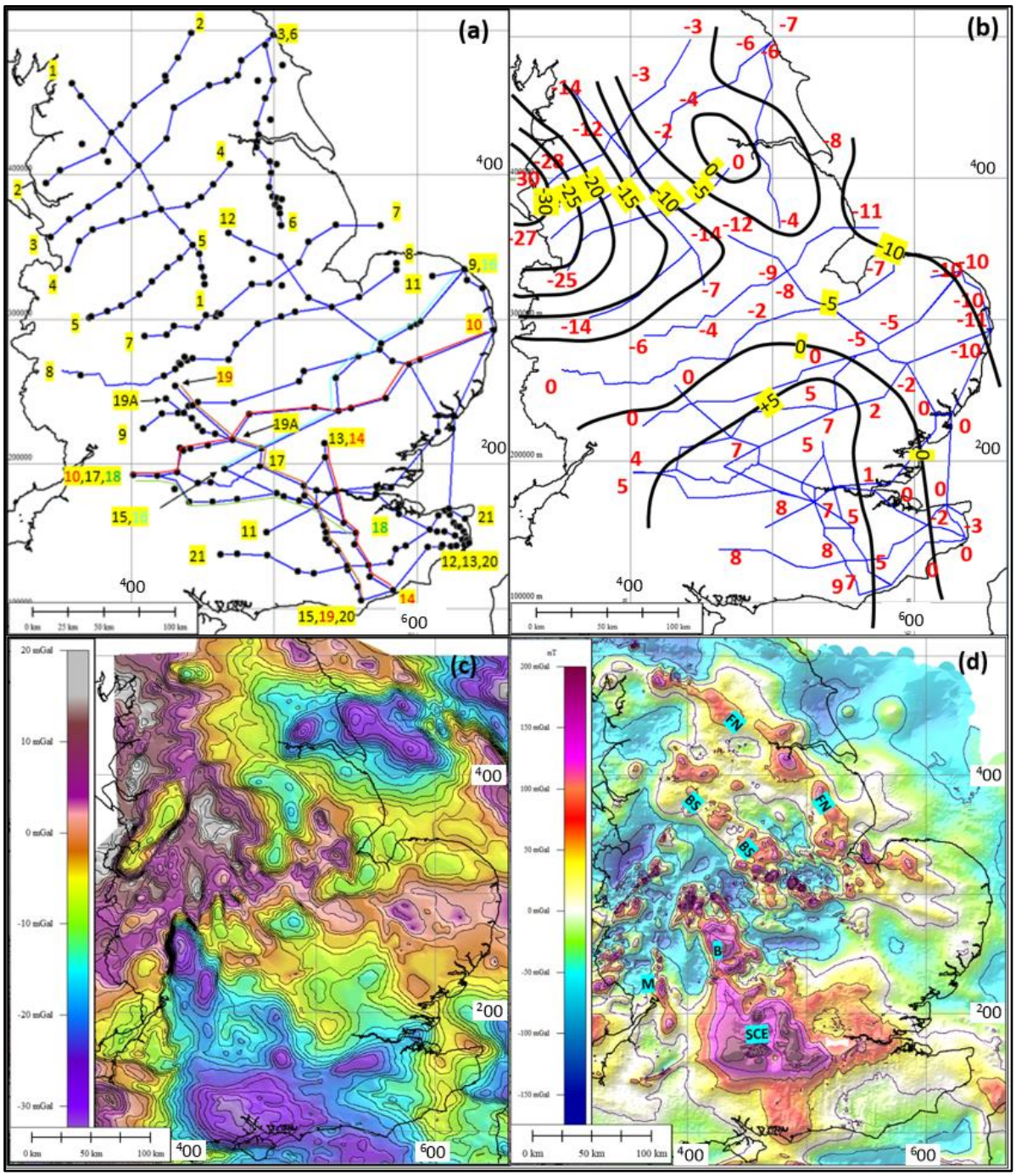



*Figure 2 (a) Location of profiles and well ties - profile numbers are shown on the ends of each line and well locations are shown as black dots (b) Assumed regional background gravity field applied to profiles, red posted numbers show 'spot' values applied in mGal (c) BGS Gravity data (BA onshore and FA offshore) gridded and contoured at 2mGal interval and (d) BGS Total Magnetic Field data gridded and contoured at 50 nT interval. The naming of the magnetic anomalies follows Beamish et al (2016) , B – Birmingham Magnetic Anomaly; FN – Furness-Norfolk Magnetic Anomaly; SCE – South Central England Magnetic Anomaly; and M – Malvern Magnetic Anomaly with one exception. The Derby-St Ives Magnetic Anomaly has been renamed as BS - Burnley to Stamford Magnetic Anomaly (see text).*

During the interpretation of gravity profiles, it is necessary to make assumptions regarding the deep-seated, long-wavelength, background regional gravity field. With an intersecting grid of profiles, such as described here, it was necessary to define a regional background variation consistent across all profiles. The estimation of this regional variation evolved as the individual profiles were interpreted and is illustrated within Figure 2(b). Red numbers show the 'spot' regional gravity values applied along

the profiles with linear interpolation between. The black contours show a manual smoothing of these 'spot' values. Such a variation was found to be necessary in order to permit reasonable fits between observed and modelled gravity values. Two notable features of the map are the high regional values, of approximately 30mGal, present over the area of the Irish Sea (Arrowsmith, et al., 2005) and the low regional values over the area of the Midlands Microcraton. Crustal thickness studies, in particular those of Hardwick (2008), show thinner crust to be present below the general area of the Irish Sea and thicker crust present beneath the Midlands Microcraton. The possible long-wavelength gravity field associated with such crustal thickness variations has been 3D modelled (description currently in preparation). The 3D results show a close similarity, in both amplitude and areal extent, with the assumed background field as deduced from the 2.5D gravity-modelled profiles. Consequently, the 3D model results were used, particularly over the East Anglia area, to refine slightly the assumed regional background gravity field, with the final result shown in Figure 2(b). The gravity data of Chacksfield & Edwards (2006) are shown in Figure 2(c) and the magnetic data of Chacksfield, et al. (2006) within Figure 2(d). In this figure, the magnetic anomalies are named according to Beamish, et al. (2016) with one exception. The Derby to St Ives Magnetic Anomaly (DSI of Beamish, et al., 2016) has been renamed as the Burnley to Stamford Magnetic Anomaly (BS), this being considered to be a more precise description of the lateral extent of the anomaly.

## Profile Models

All 2.5D profile models were computed using BGS modelling software (Pedley, et al., 1993). Models are grouped into four sections related to the area covered: (i) North of England (Profiles 1-6), (ii) Midlands Platform to Eastern England (Profiles 7-11), (iii) Eastern England to Southern England (Profiles 12-18), and (iv) Southern England (Profiles 19-21). A short description of each profile is provided together with two figures, one showing the profile itself and one showing a map with the position of the profile located upon the relevant part of the BGS solid geology map (British Geological Survey, 2020). The locations of the named wells, upon which each profile is based, are also shown on both the map and profile. Vertical 'sticks' on the profiles illustrate the approximate total depth to which each well penetrated. As far as possible, the horizontal and vertical scales are the same for all profiles and the colour scheme adopted follows that shown in Figure 3. Modelled parameters are given in the figure captions. Densities are in kg/m$^3$ and magnetic susceptibilities are in SI units. Magnetic anomalies are generally calculated on the basis of induction within the earth's present-day magnetic field. In the few cases where remanent magnetic parameters have been assumed within a model, the magnetic susceptibility has been set to zero and the assumed remanent magnetisation value (SI units) is provided followed by the assumed remanent angle of inclination. The remanent declination is assumed to be due North.

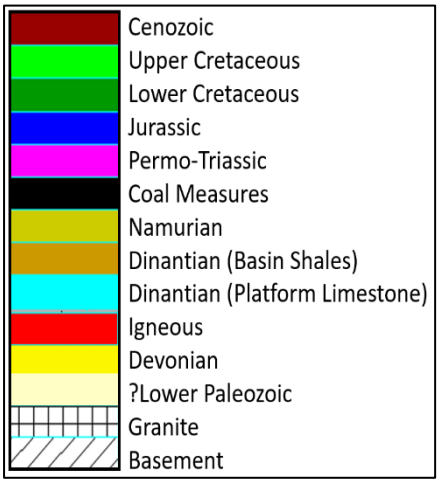



*Figure 3 Colour scheme adopted for all profiles*

It is usual to model gravity profiles as straight lines positioned so as to cross features in an orthogonal way to the general strike direction. It is important to appreciate that the models created here do not satisfy this norm and are consequently slightly unconventional in their construction. Therefore, they have additional limitations to normal profiles, and there will be places where very close agreement between observed and calculated gravity values cannot be expected, nor has it been attempted. Nevertheless, the profiles have been constructed to help identify areas where significant residual anomalies exist and consequently suggest further investigations to be worthwhile. In evaluating the gravity profile results, general agreement to within 2-3mGal has been considered acceptable. Differences greater than 5mGal merit further consideration and suggest the influence of additional sources not included on the initial model profile.

As an example, consider Profile 1. The profile has highlighted two areas of negative residual gravity anomaly, shaded blue in Figure 4. The first residual low, located between 40 and 100km along the line, has a maximum amplitude of approximately 12mgal. This is a significant anomaly, not previously recognised, and located in the area of the Central Lancashire High (Evans & Kirby, 1999). Intersecting Profiles 2 and 3 also show a similar feature, but with a much-reduced residual amplitude. A speculative interpretation in terms of a buried granite body is proposed. For the second residual low, between 150 and 170km, the profile is located across the flank of the Bingham Granite (Donato, 2019), not included in the profile model. Despite the slightly unconventional nature of the modelled profile, it has succeeded in the objective of drawing attention to two potentially interesting areas, one requiring further explanation and one possibly already understood.

The construction of the modelled lines followed a similar strategy for each profile. An initial profile of the better-understood (usually shallower) structure was constructed based upon interpreted well tops combined with available seismic interpretations and depth mapping. Simple polygonal shapes were added to the profile to represent the various stratigraphic units. Polygons were not included for those units considered to have insignificant density contrasts with the background. Estimated density values were then associated with the various stratigraphic layers and the gravity model results calculated. In areas where residual anomalies were shown to be significant, additional (usually deeper) features were introduced into the model in order to achieve agreement between observed and calculated values. Occasionally, the original shallow model was also modified slightly, where permitted by the well and mapping constraints. Following this stage, observed magnetic anomalies were considered and magnetic models incorporated. Attempts were made to match the general form of the observed magnetic profiles, with variations in wavelength offering an approximation to the source depth of the magnetic anomaly. Many of the magnetic anomalies are complex and include differing wavelength components suggestive of a mixture of contributions from sources at various depths (Beamish, et al., 2016). Consequently, interpretation of the long wavelength components, possibly suggestive of deep sources, is often unreliable. The short wavelength, shallow features are perhaps more easily interpreted. However, the magnetic results, as a whole, should be regarded as indicative rather than detailed. Following a series of iterations, a final model was created, broadly matching both gravity and magnetic observations. In some cases, a different geological concept was employed, and an alternative model produced. As for all potential field interpretations, the technique does not produce a definitive result, although it can be more powerful when integrated with other datasets as used here. However, they help to constrain possible solutions and are particularly helpful in eliminating unlikely geological concepts.

Modelling uncertainties are difficult to estimate. One of the main factors is the two-dimensional nature of the profiles discussed above. Other factors include uncertainty in the assumed layer density and susceptibility values. Further consideration of potential errors will be required in subsequent work following this initial reconnaissance investigation.

Figures 3(a), (b) and (c) are provided below as a summary of the locations of features mentioned in the text. Figure 3(a) includes various geophysical and structural features discussed together with the model profile locations. Figure 3(b) and (c) show the positions of Permo-Triassic basins, Upper Carboniferous Coal Measures and Lower Carboniferous basins used in the gravity stripping process. The outline extent of the Coal Measures is taken from Jones (2006). The interpreted locations of Devonian basins and granite bodies are also shown.

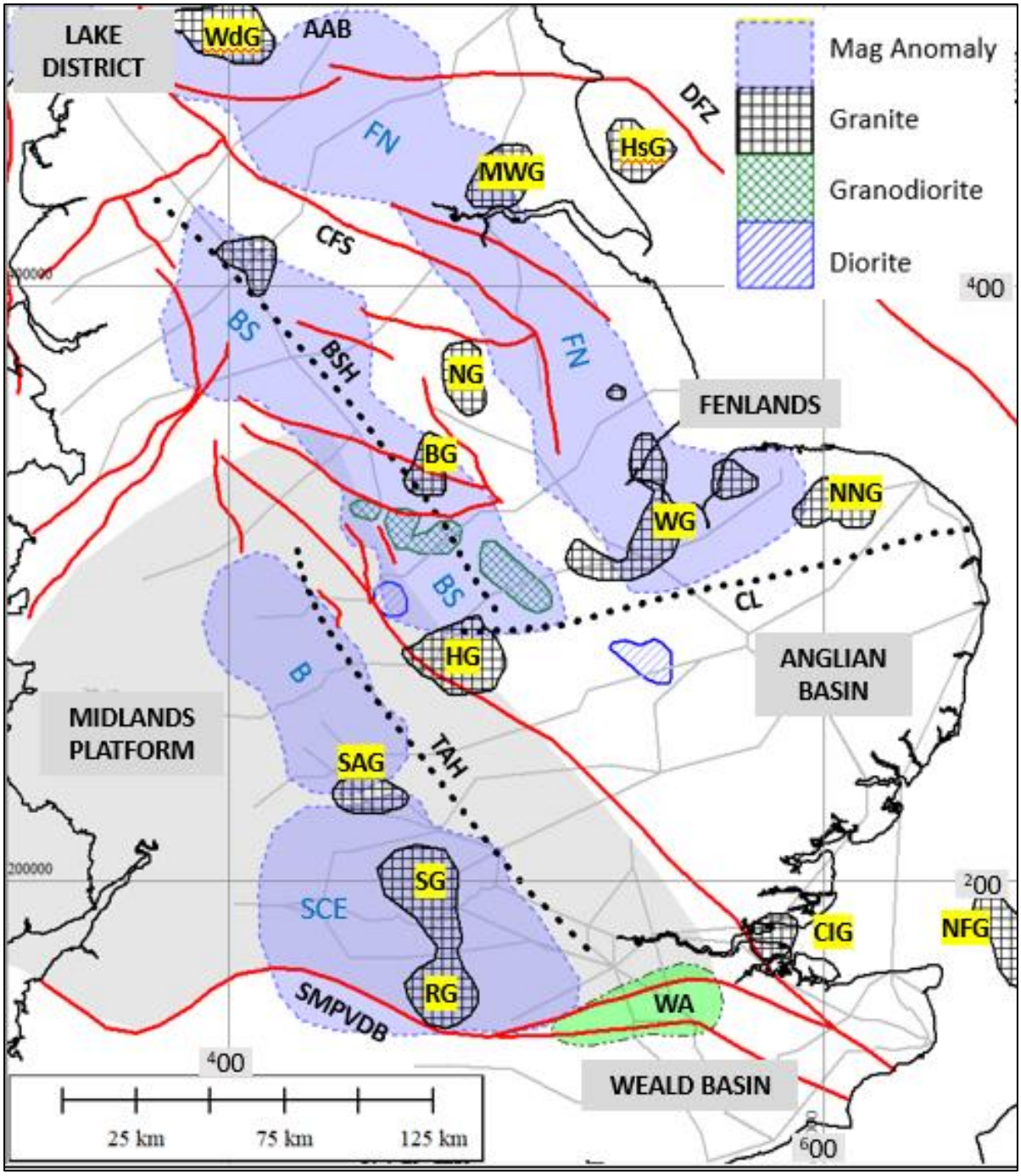



*Figure 3(a) Summary map showing the locations of geophysical and structural features discussed in the text. The model profile locations are also shown. The shaded extent of the Midlands Platform is taken from the outline of the Midlands Microcraton (Butler, 2018) with the southern boundary modified to follow the line of the Southern Midland Platform Variscan Deformation Belt (SMPVDB). Abbreviations as follows:-*

***Important fault systems/lineaments/anomalies**: CFS Craven Fault System, SMPVDB Southern Midland Platform Variscan Deformation Belt, CL Cambridge Line, DFZ Dowsing Fault Zone, BSH Burnley-Stamford High, AAB Alston-Askrigg Block, TAM Tamworth-Aylesbury High, WA Warlingham Gravity Anomaly, and magnetic anomalies FN Furness-Norfolk, BS Burnley-Stamford, B Birmingham, and SCE South Central England.*

***Granites**: HG Hollowell Granite, WG Wash Granites, MWG Market Weighton Granite, NNG North Norfolk Granite, CIG Canvey Island Granite, NFG North Foreland Granite, SG Sonning Granite, RG Reading Granite, SAG Steeple Aston Granite, BG Bingham Granite, NG Newark Granite, WdG Wensleydale Granite, and HsG Hornsea Granite.*

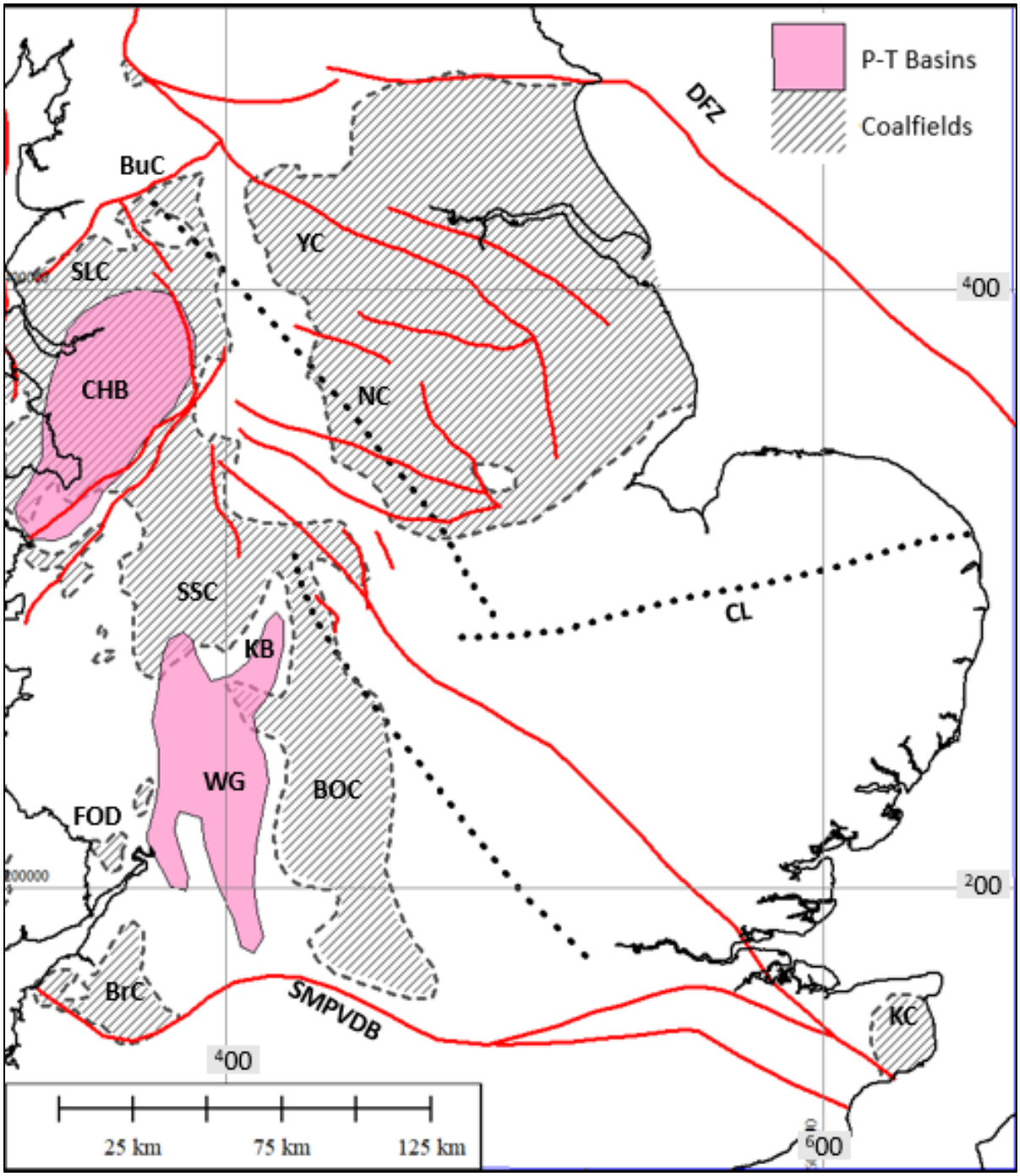



*Figure 3(b) Summary map showing the locations of Permo-Triassic basins and the distribution of Upper Carboniferous Coal Measures discussed in the text. The outline extent of the Coal Measures is taken from Jones (2006). Abbreviations are as follows:-*

***Coalfields:*** *BuC Burnley, BrC Bristol, BOC Berkshire Oxfordshire, FOD Forest of Dean, KC Kent, NC Nottingham, SLC South Lancashire, SSC South Staffordshire and YC Yorkshire.*

***Permo-Triassic Basins****: CHB Cheshire Basin, WG Worcester Graben, and KB Knowle Basin.*

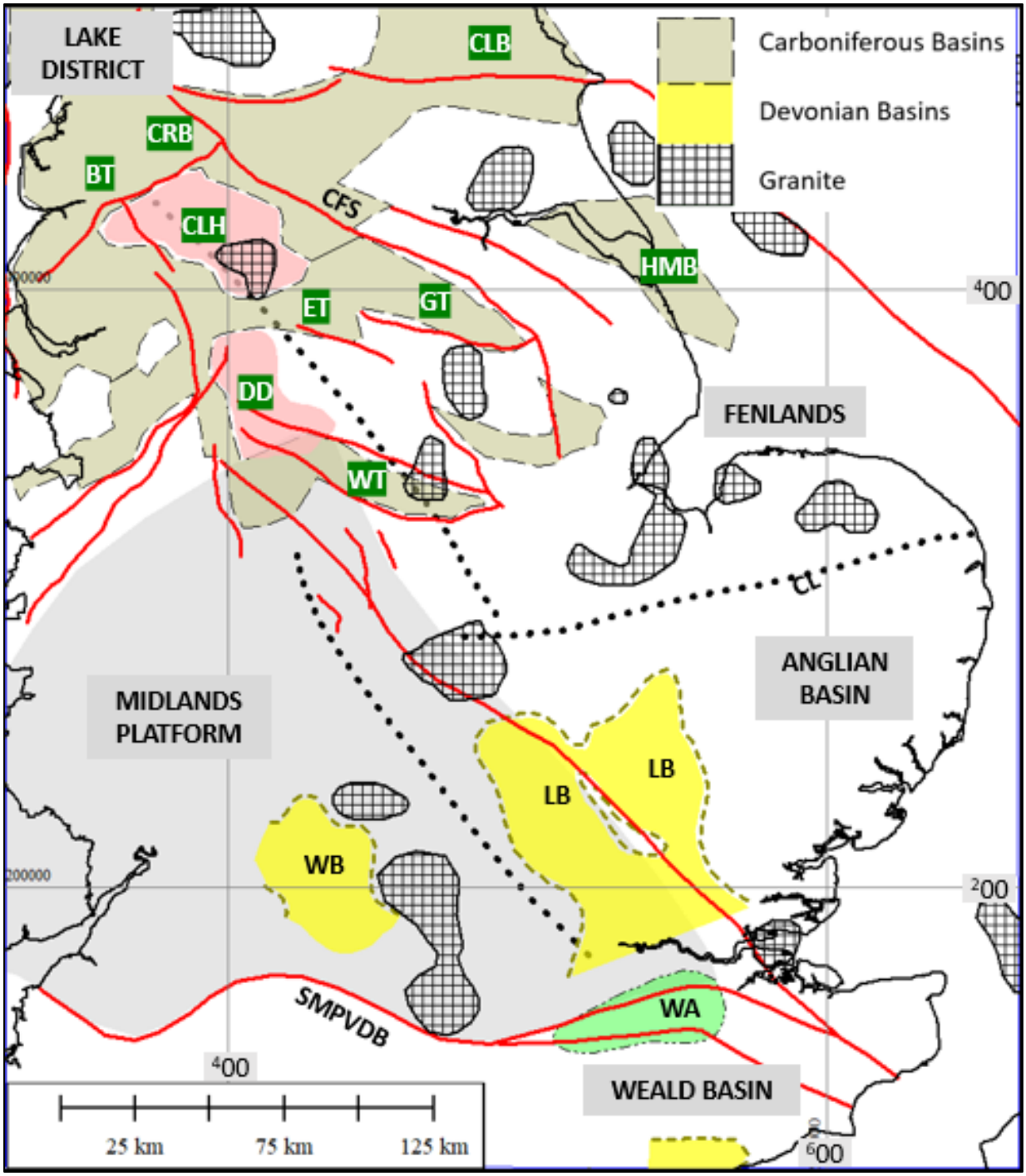
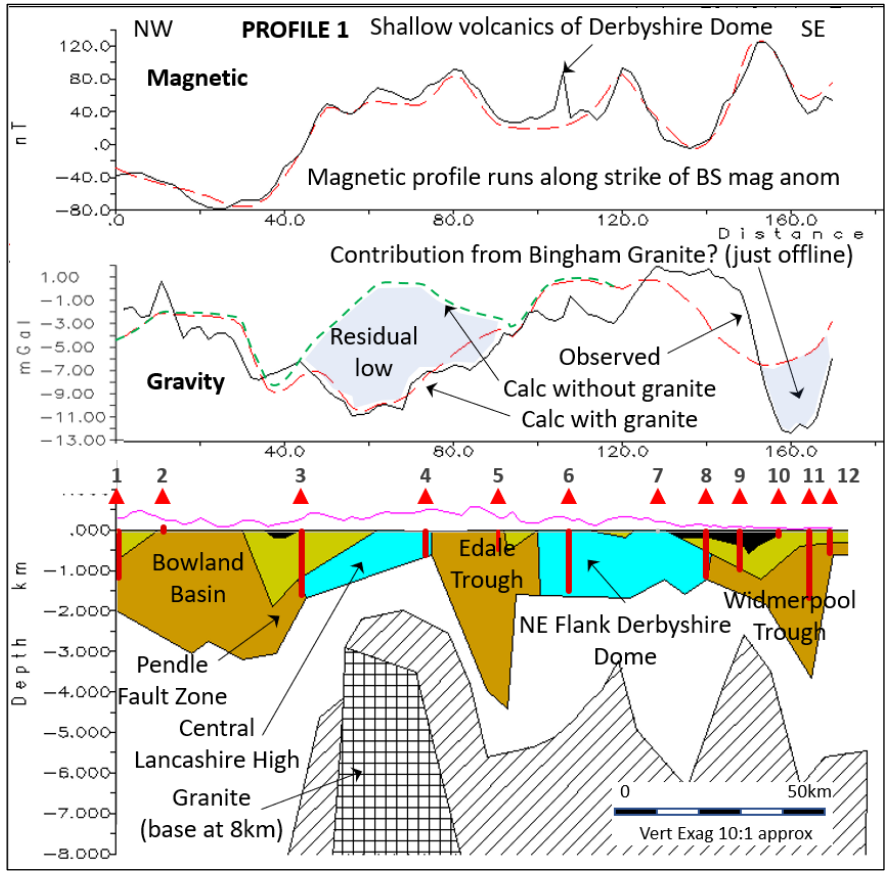



*Figure 3(c) Summary map showing the locations of Lower Carboniferous and Devonian basins discussed in the text. The locations of granites from Figure 4(a) are also shown. Abbreviations are as follows:-*
***Devonian Basins**: WB Wantage Basin and LB Luton/Cambridge Basin.*
***Carboniferous Basins and Highs**: CRB Craven Basin, BT Bowland Trough, CLB Cleveland Basin, GT Gainsborough Trough, ET Edale Trough, WT Widmerpool Trough, HMB Humber Basin, CLH Central Lancashire High, and DD Derbyshire Dome.*
***Warlingham Gravity Anomaly** WA*

## North of England

**Profile 1 – Whitmoor-1 to Hathern-1 – Northwest-Southeast orientation – Controlled by 12 wells**



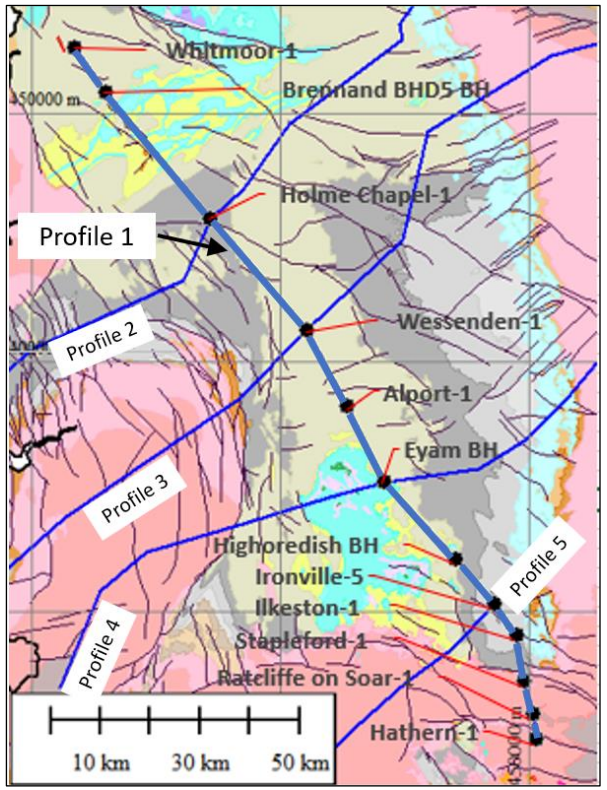




*Figure 4* ***Profile 1*** *Assumed densities are Triassic 2.55, Westphalian 2.6, Namurian 2.6, Dinantian 2.7 (Bowland and Edale Basins), Dinantian 2.68 (Widmerpool Trough), Dinantian 2.73 (carbonates), Granite 2.65. A background density of 2.72 has been assumed. Magnetic basement 2.72, 0.019 SI. The well locations are numbered as 1 Whitmoor-1, 2 Brennand BH, 3 Holme Chapel-1, 4 Wessenden-1, 5 Alport-1, 6 Eyam BH, 7 Highoredish BH, 8 Ironville-5, 9 Ilkeston-1, 10 Stapleford-1, 11 Ratcliffe on Soar-1 and 12 Hathern-1*

**Profile 1 – Whitmoor-1 to Hathern-1 – Northwest-Southeast orientation – Controlled by 12 wells**

The profile commences in the northwest within the Bowland Basin with Namurian rocks outcropping at the surface. To the south, the outcrop changes to deformed Lower Carboniferous section as the profile crosses the Pendle Fault zone, marking the northern edge of the Central Lancashire High (Evans & Kirby, 1999). The Central Lancashire High is a Lower Carboniferous palaeohigh, characterised by shelf carbonate deposition as encountered in the Holme Chapel–1 well. Its extension to the southeast was proved by the Wessenden-1 borehole. A residual negative gravity anomaly is associated with this palaeohigh. The presence of local Lower Carboniferous carbonate build-ups (Evans & Kirby, 1999) together with flanking magnetic anomalies (see Profiles 2 and 3) may suggest the anomaly to be caused by a buried granite intrusion, albeit significantly smaller than the Weardale and Wensleydale Granites (Bott, 1961; Bott, 1967; Kimbell, et al., 2006) located to the north. The palaeohigh lies on the northern end of the northwest-southeast trending Burnley-Stamford Magnetic Anomaly (BS in Figure 2) (Wills, 1978; Pharaoh, 2018). This feature is associated with Ordovician metasediments which underlie the Upper Paleozoic section with a maturity break, as seen in the Holme Chapel–1 well in the northwest of the Ridge and Ironville-5 in the southeast (Molyneux, 2001; FINA, 1987; Quintana Petroleum, 1974). The deformation and metamorphism are thought to be due to the Acadian deformation event. Further south, the profile crosses the Edale Trough, a Lower Carboniferous basinal area, proved by the Alport-1 well, before rising onto the East Midlands Shelf and its northwest extension, the Derbyshire Dome, with Lower Carboniferous shelf carbonates at the surface. South of the Ironville-5 well, the profile crosses the Widmerpool Trough, a Lower Carboniferous basinal area, proved by the Widmerpool-1 well, where Namurian rocks subcrop beneath Triassic cover, before rising onto the Midlands Platform at the southern end (Fraser & et al, 2003).

| Profile 1 | Well No | Well Name | X | Y | Distance Along Profile (km) | TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 1 | 1 | Whitmoor-1 | 358744 | 463150 | 0 | 1240 | Lower Carboniferous |
| 1 | 2 | Brennand BHD5 BH | 364933 | 454302 | 11 | -122 | Lower Carboniferous |
| 1 | 3 | Holme Chapel-1 | 386030 | 428970 | 44 | 1711 | Sequence 2 (Ordovician) |
| 1 | 4 | Wessenden-1 | 405460 | 406310 | 74 | 631 | Sequence 2 (Ordovician) |
| 1 | 5 | Alport-1 | 413612 | 391055 | 91 | 495 | Lower Carboniferous |
| 1 | 6 | Eyam BH | 420960 | 376030 | 108 | 1621 | Sequence 2 (Ordovician) |
| 1 | 7 | Highoredish BH | 435401 | 360322 | 129 | -26 | Lower Carboniferous |
| 1 | 8 | Ironville-5 | 442996 | 351418 | 141 | 1216 | Sequence 1 (Camb-Trem) |
| 1 | 9 | Ilkeston-1 | 447537 | 345172 | 149 | 1036 | U. Carb (Namurian) |
| 1 | 10 | Stapleford-1 | 449066 | 335947 | 158 | 108 | U. Carb (Namurian) |
| 1 | 11 | Ratcliffe on Soar-1 | 450818 | 329125 | 165 | 1802 | Lower Carboniferous |
| 1 | 12 | Hathern-1 | 451580 | 324160 | 170 | 586 | Lower Carboniferous |

*Table 1 Profile 1 well data*

**Profile 2 – Croxteth-1 to Harsley-1 – Southwest-Northeast orientation – Controlled by 12 wells**

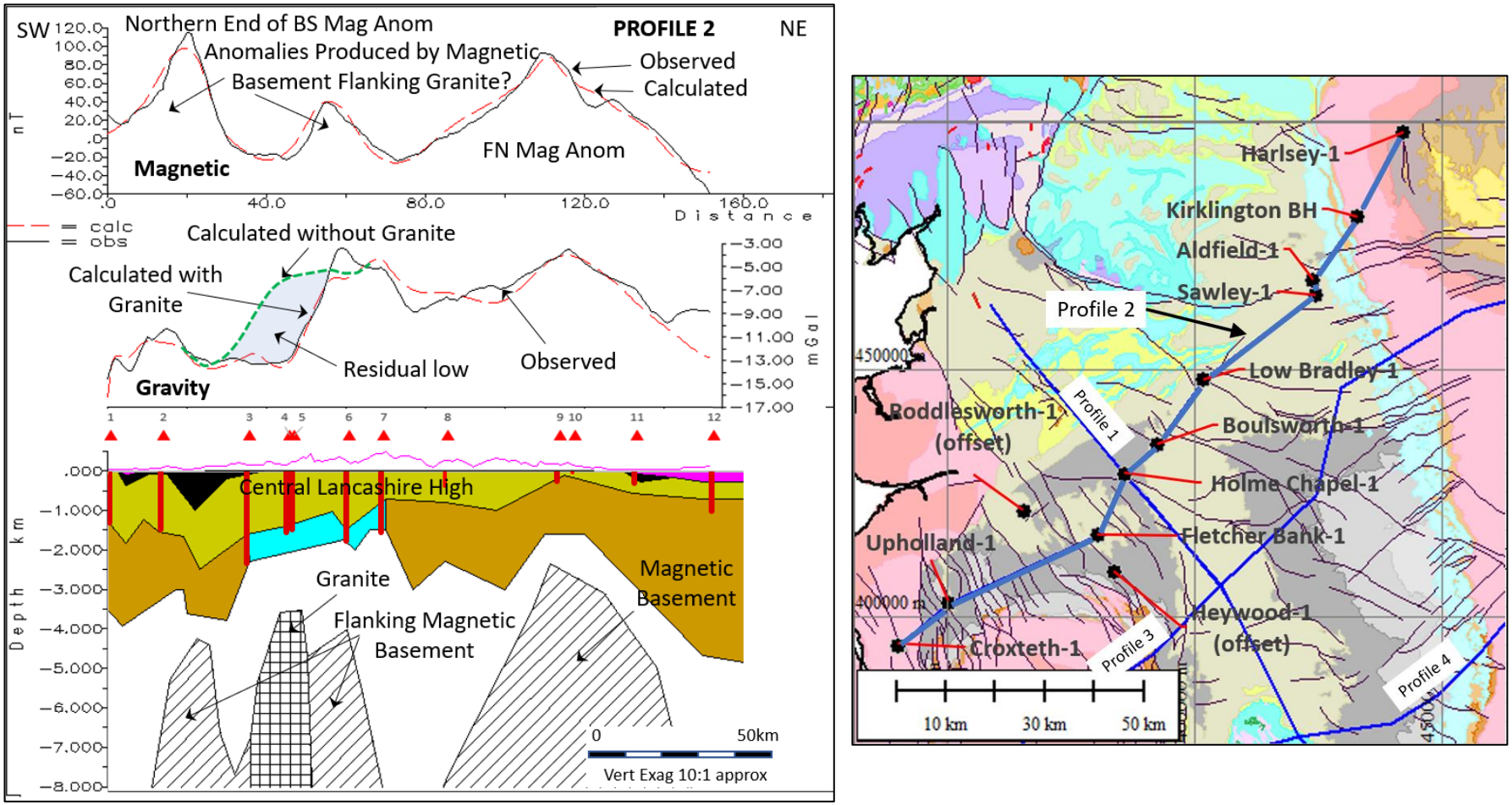



*Figure 5* ***Profile 2*** *Assumed densities are Permo-Triassic 2.45, Westphalian 2.6, Namurian 2.6, Visean and Tournaisian Sst/Sh 2.67, Visean and Tournaisian Lmst 2.73, Granite 2.65, Magnetic Basement SW of granite 2.72, 0.018 SI, Magnetic Basement NE of Granite 2.735, 0.01 SI, Magnetic Basement NE end of profile 2.72, 0.014 SI. The well locations are numbered as 1 Croxteth-1, 2 Upholland-1, 3 Roddlesworth-1 (offset), 4 Heywood-1 (offset), 5 Fletcher Bank-1, 6 Holme Chapel-1, 7 Boulsworth-1, 8 Low Bradley-1, 9 Sawley-1, 10 Aldfield-1, 11 Kirklington BH and 12 Harsley-1.*

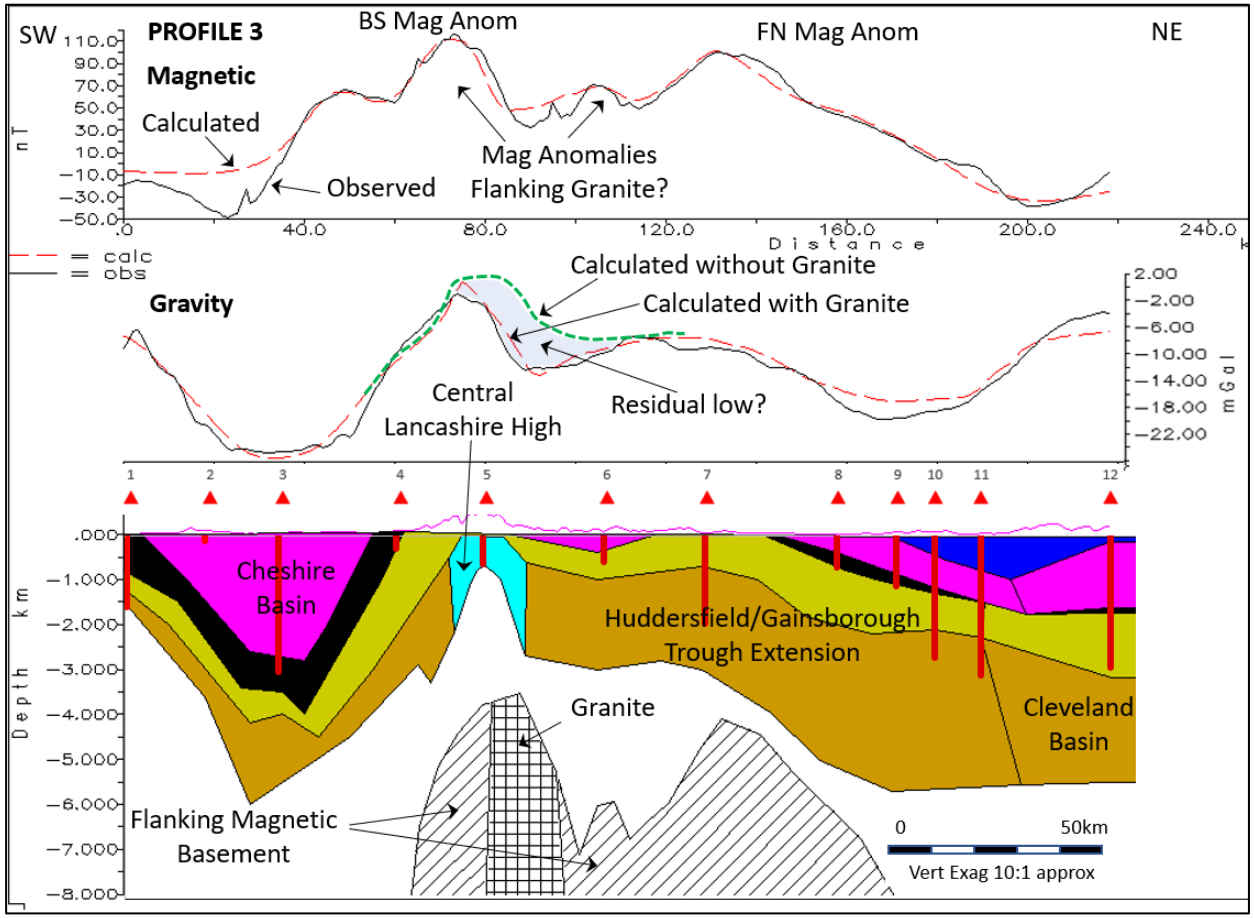
**Profile 2 – Croxteth-1 to Harsley-1 – Southwest-Northeast orientation – Controlled by 12 wells**

At the southwestern end of the profile, Permo-Triassic rocks outcrop at the surface but after crossing a fault, just to the northeast of Croxteth-1, Namurian to Westphalian section outcrops. The profile crosses the Lancashire Coalfield where a thick Upper Carboniferous section is thought to overlie a thick Lower Carboniferous basinal sequence. This basinal sequence terminates against faults which mark the southwestern edge of the Central Lancashire High. The profile crosses the very northern end of the Burnley-Stamford Magnetic Anomaly (BS, Figure 2), here interpreted simply as shallower magnetic basement. The anomaly is problematic and alternative possible sources have been suggested (Beamish, et al., 2016) including Ordovician intrusive rocks (Pharaoh, et al., 1993; Allsop, 1987) or Precambrian basement (Cornwell & Walker, 1989). Lower Carboniferous shelf carbonates are developed over the Central Lancashire High that lies at the northern end of the Burnley-Stamford Magnetic Anomaly. This palaeohigh is associated with shallow Paleozoic section, as proved by the Roddlesworth-1, Holme Chapel-1, Heywood-1 and Boulsworth-1 wells. A negative residual gravity anomaly is associated with the Central Lancashire High and is possibly explained by the presence of an underlying granite with flanking magnetic anomalies (see Profiles 1, 2 and 3). To the northeast of the Boulsworth-1 well, Lower Carboniferous basinal sequences are thought to be developed across a bounding fault, although this is unproven by well data. These basinal sequences extend to the northeast into the Craven Basin where they outcrop. The line continues to the northeast, crossing the Furness-Norfolk Magnetic Anomaly (FN, Figure 2). As for the Burnley-Stamford Magnetic Anomaly, the interpretation of the Furness-Norfolk Anomaly is debateable, and alternative explanations have been offered including Precambrian basement (Wills, 1978), Ordovician arc magmatism (Pharaoh et al, 1993, 1995), early Paleozoic magnetic metasediments (Lee, et al., 1993) and Devonian metamorphism (Allsop, 1987). Here, the feature is modelled simply as a basement magnetic ridge although our preference is for an interpretation involving magnetic sedimentary sequences in the Ordovician (Wilson & Cornwell, 1982) supplemented by Upper Ordovician igneous activity. The line ends on Permo-Triassic outcrop at the Harlsey-1 well where the observed gravity values rise slightly, possibly associated with the Cleveland Basin inversion (see Profile 3).

| Profile 2 | Well No | Well Name | X | Y | Distance Along Profile | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 2 | 1 | Croxteth-1 | 340316 | 394266 | 0 | 1260.3 | Lower Carboniferous |
| 2 | 2 | Upholland-1 | 350440 | 402880 | 13.3 | 1439.5 | U. Carb (Namurian) |
| 2 | 3 | Roddlesworth-1 (offset) | 365630 | 421264 | 35 | 2273.1 | Lower Carboniferous |
| 2 | 4 | Heywood-1 (offset) | 383851 | 408976 | 45 | 1499 | Lower Carboniferous |
| 2 | 5 | Fletcher Bank-1 | 380530 | 416440 | 46.3 | 1434.1 | U. Carb (Namurian) |
| 2 | 6 | Holme Chapel-1 | 386030 | 428970 | 60 | 1710.8 | Sequence 2 (Ordovician) |
| 2 | 7 | Boulsworth-1 | 392685 | 434790 | 68.8 | 1493.8 | U.Devonian |
| 2 | 8 | Low Bradley-1 | 401950 | 447860 | 84.9 | 344.7 | U. Carb (Namurian) |
| 2 | 9 | Sawley-1 | 424510 | 465020 | 113.2 | 216.1 | Lower Carboniferous |
| 2 | 10 | Aldfield-1 | 424057 | 468113 | 117 | -59.7 | Lower Carboniferous |
| 2 | 11 | Kirklington BH | 432879 | 480913 | 132.6 | 264 | U. Carb (U. Coal Measures) |
| 2 | 12 | Harlsey-1 | 442230 | 498070 | 152 | 965.6 | Lower Carboniferous |

*Table 2 Profile 2 well data*

**Profile 3 – Milton Green-1 to Cloughton-1 – Southwest-Northeast orientation – Controlled by 12 wells**



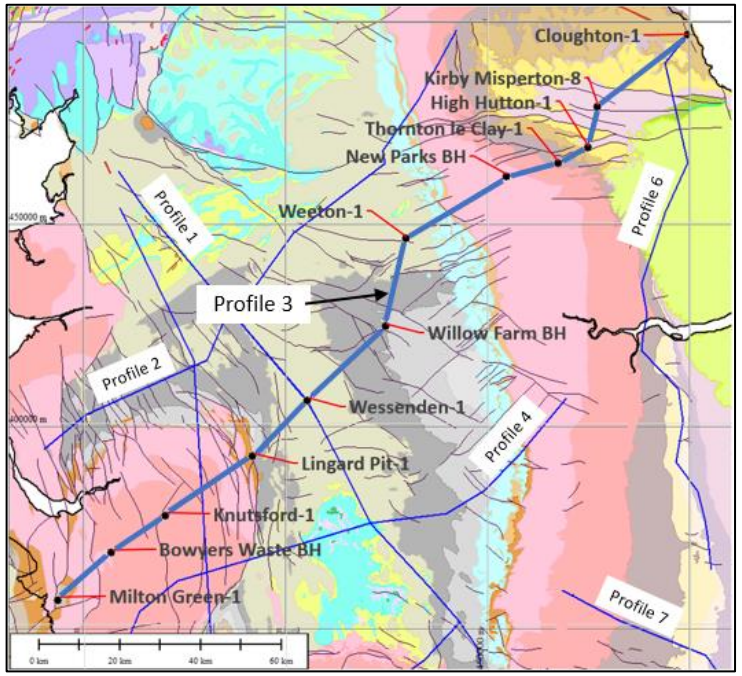




*Figure 6* ***Profile 3*** *Assumed densities are Jurassic 2.6, Permo-Triassic 2.55/2.65(Cleveland Basin inverted), Westphalian 2.6, Namurian 2.6/2.7 (inverted), Visean and Tournaisian Sst/Sh 2.68/2.72 (inverted), Visean and Tournaisian Lmst 2.75, Granite 2.62, 0.005 SI, Magnetic Basement SW of Granite 2.73, 0.015 SI, Magnetic Basement NE of Granite 2.72, 0.017 SI. The well locations are numbered as 1 Milton Green-1, 2 Bowyers Waste BH, 3 Knutsford-1, 4 Lingard Pit-1, 5 Wessenden-1, 6 Willow Farm BH, 7 Weeton-1, 8 New Parks BH, 9 Thornton le Clay-1, 10 High Hutton-1, 11 Kirby Misperton-8 and 12 Cloughton-1.*

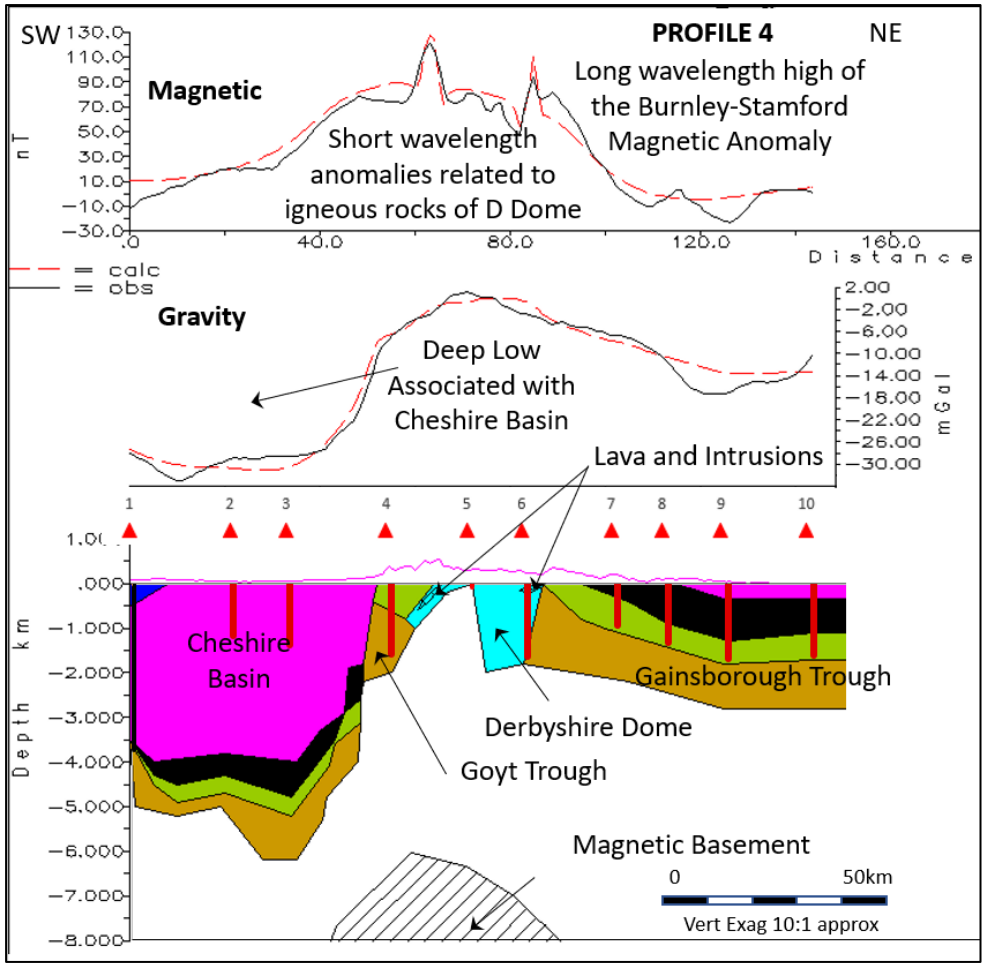
**Profile 3 – Milton Green-1 to Cloughton-1 – Southwest-Northeast orientation – Controlled by 12 wells**

The south-western end of the profile begins in the Cheshire Basin where a thick Permo-Triassic section overlies an inverted Carboniferous Basin (Mikkelsen & Floodpage, 1997). The profile has been generated using the Carboniferous structure maps of Smith, et al. (2005) and Kirby, et al. (2000). The deep gravity low associated with the low-density sediments within the Permo-Triassic basin dominates the gravity anomaly such that variations within the underlying, deeply-buried Carboniferous sediments are unlikely to be resolved using the gravity data alone. The northeastern edge of the Cheshire Basin is crossed near the Lingard Pit borehole and appears to be faulted. This margin lies close to the southeastern edge of the Central Lancashire High over which the Lower Carboniferous shelf carbonates are developed, as proved by the Wessenden-1 well. A possible negative residual gravity anomaly is associated with parts of the Central Lancashire High and may be best explained by the presence of an underlying granite, although this is better displayed on Profile 1. The profile crosses the northern margin of the Central Lancashire High into the basinal sequences deposited within the variously named Huddersfield Basin or Gainsborough Trough Extension (Aitkenhead, et al., 2002). Over much of the profile, Namurian to Westphalian section outcrops at the surface, but northeastwards, beyond the Weeton-1 borehole, a progressively younger outcrop of Permian to Jurassic rocks is encountered as the profile crosses into the Cleveland Basin. This Basin has undergone two phases of subsidence and inversion, initially in the Carboniferous and later in the Mesozoic and Tertiary (Doornenbal, H. et al., 2010). The enhanced density resulting from these burial and uplift phases may partially explain the gravity anomalies in the area.

| Profile 3 | Well No | Well Name | X | Y | Distance Along Profile (km) | TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 3 | 1 | Milton Green-1 | 343744 | 356926 | 0 | 1569 | Sequence 2 (Ordovician) |
| 3 | 2 | Bowyers Waste BH | 356860 | 368810 | 18 | 116 | Triassic |
| 3 | 3 | Knutsford-1 | 370270 | 377860 | 34 | 3000 | U. Carb (Westphalian) |
| 3 | 4 | Lingard Pit-1 | 391890 | 392540 | 60 | 288 | U. Carb (Namurian) |
| 3 | 5 | Wessenden-1 | 405460 | 406310 | 79 | 631 | Sequence 2 (Ordovician) |
| 3 | 6 | Willow Farm BH | 424703 | 424703 | 106 | 574 | U. Carb (Namurian) |
| 3 | 7 | Weeton-1 | 429809 | 446385 | 128 | 1929 | Lower Carboniferous |
| 3 | 8 | New Parks BH | 454580 | 461834 | 158 | 695 | U. Carb (U. Coal Measures) |
| 3 | 9 | Thornton le Clay-1 | 467367 | 465120 | 171 | 1098 | U. Carb (U. Coal Measures) |
| 3 | 10 | High Hutton-1 | 474782 | 468872 | 179 | 2681 | Lower Carboniferous |
| 3 | 11 | Kirby Misperton-8 | 477136 | 479004 | 189 | 3068 | Lower Carboniferous |
| 3 | 12 | Cloughton-1 | 499392 | 496802 | 218 | 2904 | U. Carb (Namurian) |

*Table 3 Profile 3 well data*

**Profile 4 – Prees-1 to Hatfield-1 – Southwest-Northeast orientation – Controlled by 10 wells**



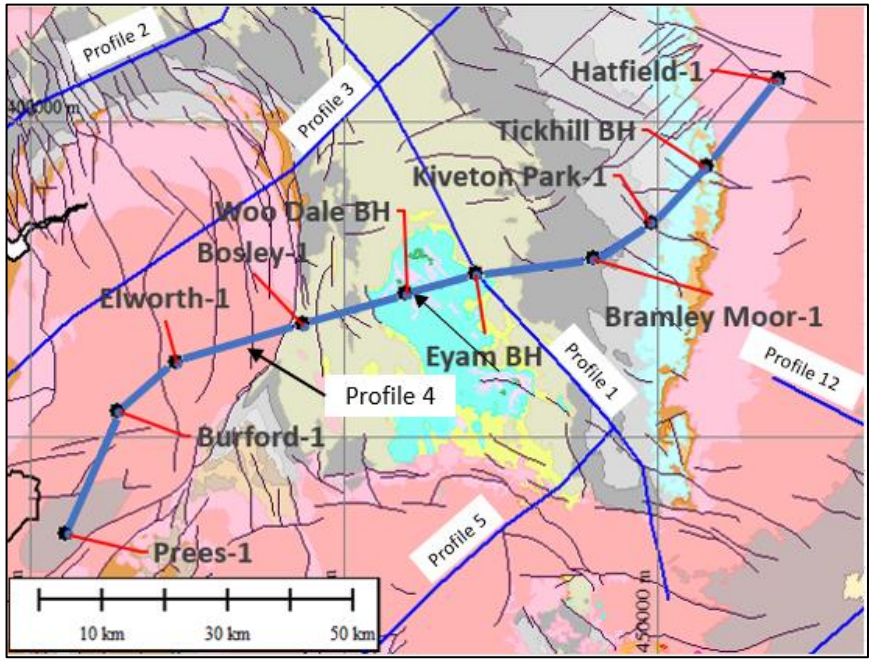




*Figure 7* ***Profile 4*** *Assumed densities are Jurassic 2.5, Permo-Triassic 2.5/2.55 (Cheshire Basin), Westphalian 2.55/2.6 (beneath Cheshire Basin), Namurian 2.6, Visean and Tournaisian Sst/Sh 2.7, Visean and Tournaisian Lmst 2.73, Magnetic Basement 2.72, 0.017 SI, Igneous Rocks of Derbyshire Dome 2.72, 1.2SI 160°(NE) and 2.72, 1.2SI, 100° (SW). The well locations are numbered as 1 Prees-1, 2 Burford-1, 3 Elworth-1, 4 Bosley-1, 5 Woo Dale BH, 6 Eyam BH, 7 Bramley Moor BH, 8 Kiveton-1, 9 Tickhill BH, and 10 Hatfield-1.*

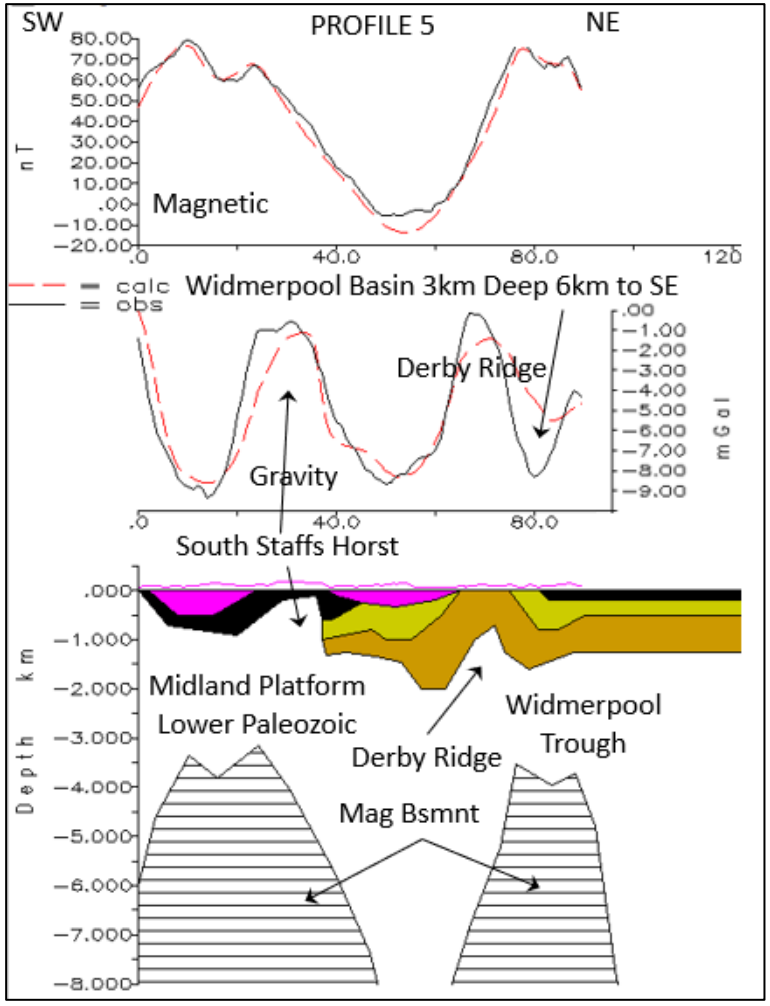
**Profile 4 – Prees-1 to Hatfield-1 – Southwest-Northeast orientation – Controlled by 10 wells**

The southwestern end of the profile begins within the Cheshire Basin where a thick Permo-Triassic basin overlies an inverted Carboniferous basin. Within the vicinity of the Press-1 and Burford-1 wells, interpretations of the Carboniferous section differ. Profile 4 follows the interpretation of Smith, et al. (2005), but Mikkelsen & Floodpage (1997) show stronger inversion with complete removal of the Carboniferous interval. Crossing the north-eastern bounding fault of the Cheshire Basin, the outcrop changes from Permo-Triassic to Namurian. In this area, a deep-water basinal section is encountered in the Bosley-1 well located within the Goyt Trough, a Carboniferous basinal area which is believed to be a northerly extension of the Widmerpool Trough. Further north, the profile crosses a fault which bounds the western edge of the Derbyshire Dome, a Lower Carboniferous palaeohigh over which shelf carbonates were deposited. This palaeohigh is thought to be rooted on a basement ridge that was formed during the Acadian movements and the longer wavelength magnetic component of the Burnley to Stamford Magnetic Anomaly may suggest shallow (top at 6km in model) magnetic basement. The source of this postulated magnetic basement is unknown, but suggestions include Precambrian Uriconian volcanic rocks (Rees, et al., 1996) (Cornwell & Walker, 1989), magmatism of late Ordovician age (Pharaoh, et al., 1993) or our preferred interpretation involving high susceptibility magnetic sediments of Ordovician age, as discussed for Profile 2. Outcropping Carboniferous lava, tuffs and shallow intrusions of the Derbyshire Dome contribute short wavelength anomalies to the magnetic signature across the high. The northeastern edge of the Derbyshire Dome is thought to be a fault zone which also forms the southwestern margin of the Gainsborough Trough, containing a thick Carboniferous basinal sequence. At the surface, the outcrop youngs from Upper Carboniferous Westphalian to Permian (beyond Bramley Moor-1) and to Triassic (beyond Tickhill BH).

| Profile 4 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 4 | 1 | Prees-1 | 355727 | 334474 | 0 | 3732 | Sequence 2 (Ordovician) |
| 4 | 2 | Burford-1 | 363831 | 354119 | 21.3 | 1159.4 | Triassic Ss |
| 4 | 3 | Elworth-1 | 373137 | 361733 | 33.3 | 1368.5 | Triassic Ss |
| 4 | 4 | Bosley-1 | 393438 | 367825 | 54.5 | 1564 | Lower Carboniferous |
| 4 | 5 | Woo Dale BH | 409850 | 372840 | 71.6 | 69.6 | Sequence 2 (Ordovician) |
| 4 | 6 | Eyam BH | 420960 | 376030 | 83.2 | 1621 | Sequence 2 (Ordovician) |
| 4 | 7 | Bramley Moor-1 | 439756 | 378508 | 102.2 | 925.9 | Lower Carboniferous |
| 4 | 8 | Kiveton Park-1 | 448979 | 384136 | 113 | 1312.1 | Lower Carboniferous |
| 4 | 9 | Tickhill BH | 457738 | 392975 | 125.5 | 1681.5 | U. Carb (Namurian) |
| 4 | 10 | Hatfield-1 | 469313 | 406965 | 143.6 | 1599.7 | U. Carb (Namurian) |

*Table 4 Profile 4 well data*

**Profile 5 – Coalport G1 to Ironville-5 – Southwest-Northeast orientation – Controlled by 9 wells**



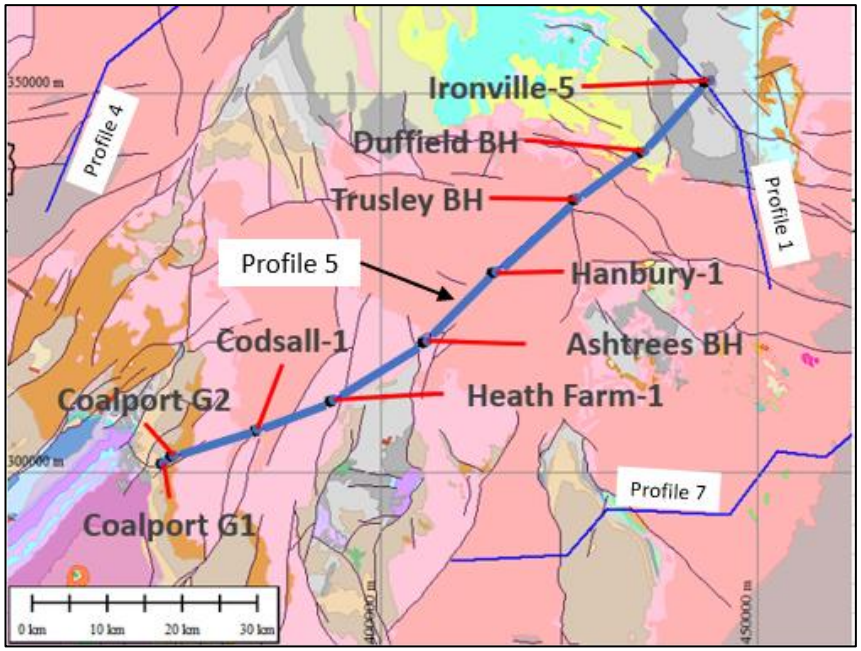




*Figure 8* ***Profile 5*** *Assumed densities are Permo-Triassic 2.4 (Shallow Cheshire Basin), Westphalian 2.5/2.55 (Beneath Cheshire Basin), Namurian 2.6, Visean and Tournaisian Sst/Sh 2.7, Visean and Tournaisian Lmst 2.73, Magnetic Basement 2.72, 0.015 SI. The well locations are numbered as 1 Coalport G1, 2 Coalport G2, 3 Codsall-1, 4 Heath Farm-1, 5 Ashtrees BH, 6 Hanbury-1, 7 Trusley-1, 8 Duffield BH and 9 Ironville-5.*

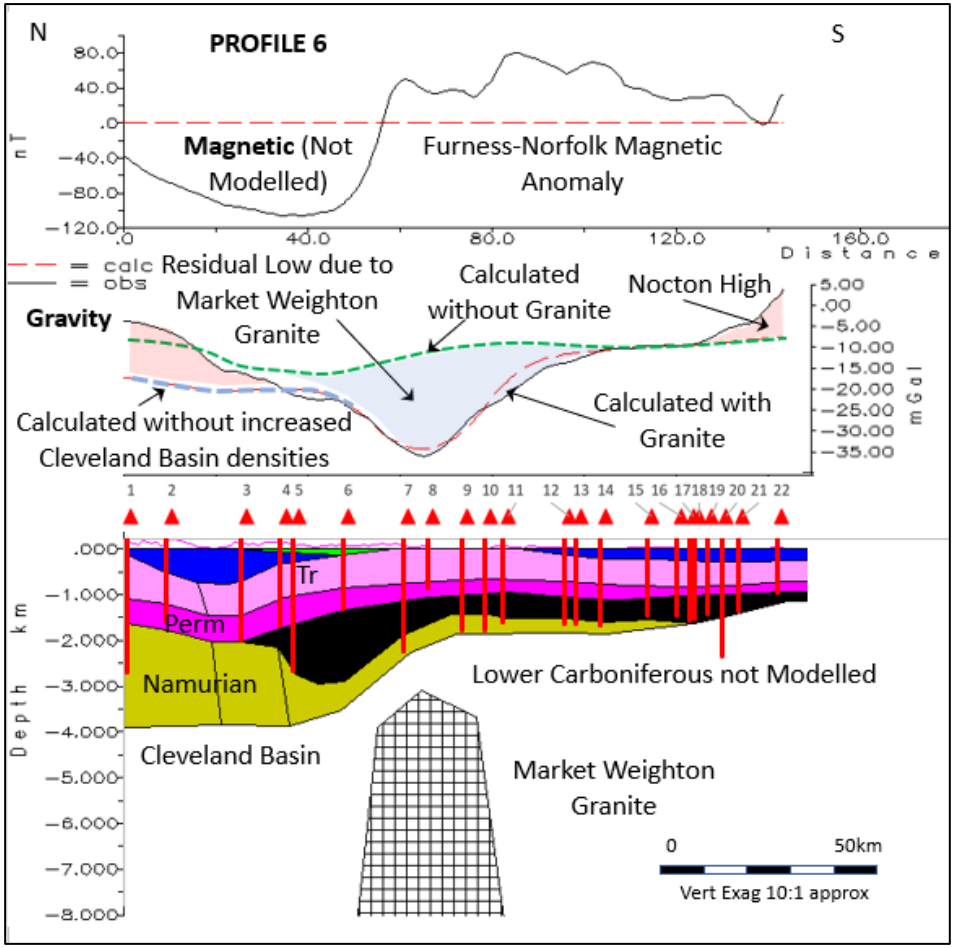
**Profile 5 – Coalport G1 to Ironville-5 – Southwest-Northeast orientation – Controlled by 9 wells**

The southwestern end of the profile begins on the Midland Platform with Permo-Triassic section cropping out at the surface. The well data indicate Permo-Triassic sediments overlying a Westphalian section which in turn unconformably overlies a Lower Paleozoic section as shown by the Heath Farm-1 well (Shell, 1984). Further to the northeast, beyond the Ashtrees borehole, the profile crosses into the Widmerpool Trough, where a thick Lower Carboniferous basinal sequence is preserved. The Widmerpool Trough deepens significantly just to the southeast of the profile, and this probably accounts for the poor fit between the observed and calculated gravity values. The northern edge of the Trough lies to the south of the Ironville-5 well and marks the change, in the Lower Carboniferous, from basinal shale deposition in the Trough to shallow water carbonates sedimentation over the Shelf. The margin of the Widmerpool Trough also seems to mark the southwestern limit of Acadian deformation and metamorphism in the north Midlands, since the Lower Palaeozoic in Ironville-5 shows significantly higher maturity and greater deformation than the same interval in the wells to the south and west (Molyneux, 2001; Merriman R et al., 1993). A progressively older outcrop from Permo-Triassic to Upper Carboniferous, Namurian and Westphalian is seen at the surface to the northeast of the Duffield borehole. Overall, the observed gravity profile is dominated by the shallow basins of low density Permo-Triassic sediments. The north-eastern end of the profile extends onto the Burnley to Stamford Magnetic Anomaly modelled here simply as a shallowing of magnetic basement (Cornwell & Walker, 1989), although an alternative interpretation involving Ordovician intrusive rocks has been suggested (Pharaoh, et al., 1993). As for the Furness-Norfolk Anomaly (see Profile 2), we prefer an interpretation involving magnetic sedimentary sequences in the Ordovician augmented by Upper Ordovician igneous activity.

| Profile 5 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 5 | 1 | Coalport G1 | 370940 | 301040 | 0 | 37.5 | Silurian |
| 5 | 2 | Coalport G2 | 372210 | 301910 | 1.5 | 210 | Silurian |
| 5 | 3 | Codsall-1 | 383331 | 305375 | 13.2 | 1060.3 | Silurian |
| 5 | 4 | Heath Farm-1 | 393325 | 309256 | 23.9 | 1744.3 | Precambrian |
| 5 | 5 | Ashtrees BH | 405671 | 317031 | 38.5 | 830.6 | U. Carb (Namurian) |
| 5 | 6 | Hanbury-1 | 414840 | 326200 | 51.5 | 1333.4 | Lower Carboniferous |
| 5 | 7 | Trusley BH | 425478 | 335880 | 65.9 | 75.3 | Lower Carboniferous |
| 5 | 8 | Duffield BH | 434280 | 342170 | 76.7 | 1155.2 | Lower Carboniferous |
| 5 | 9 | Ironville-5 | 442996 | 351418 | 89.4 | 1215.5 | Sequence 1 (Camb-Trem) |

*Table 5 Profile 5 well data*

**Profile 6 – Cloughton-1 to Nocton-1 – North-South orientation – Controlled by 22 wells**



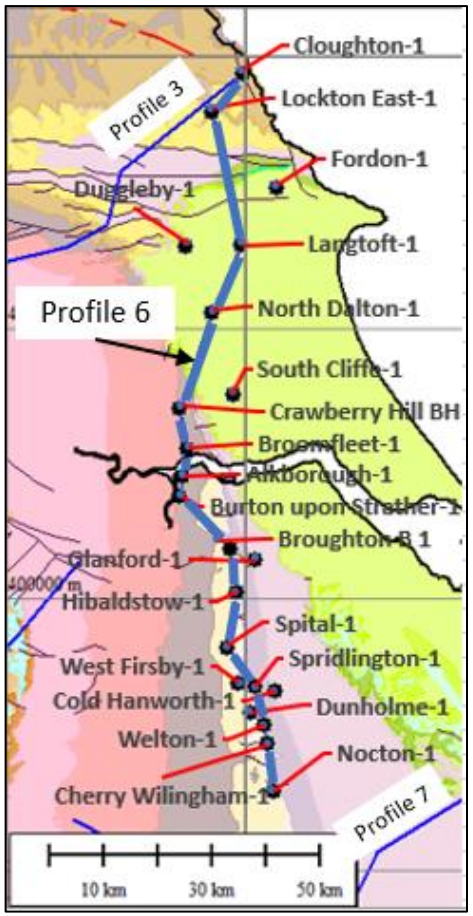




*Figure 9* ***Profile 6*** *Assumed densities are Cretaceous 2.3, Jurassic 2.5/2.62 (Inverted Cleveland Basin), Triassic 2.55/2.65 (Inverted Cleveland Basin), Permian 2.6, Westphalian 2.65, Namurian 2.7/2.67/2.65 (Densest to the N beneath Cleveland Basin), Lower Carboniferous not modelled and Granite 2.6. The well locations are numbered as 1 Cloughton-1, 2 Lockton East-1, 3 Fordon-1 (offset), 4 Langtoft-1 (offset), 5 Duggleby-1, 6 North Dalton-1, 7 Crawberry Hill BH, 8 South Cliffe-1, 9 Broomfleet-1, 10 Alkborough-1, 11 Burton upon Strather-1, 12 Broughton-1(A), 13 Glanford-1, 14 Hilbaldstow-1, 15 Spital-1, 16 West Firsby-1, 17 Spridlington-1, 18 Cold Hanworth-1, 19 Dunholme-1, 20 Welton-1, 21 Cherry Wilmingham-1 and 22 Nocton-1.*

**Profile 6 – Cloughton-1 to Nocton-1 – North-South orientation – Controlled by 22 wells**

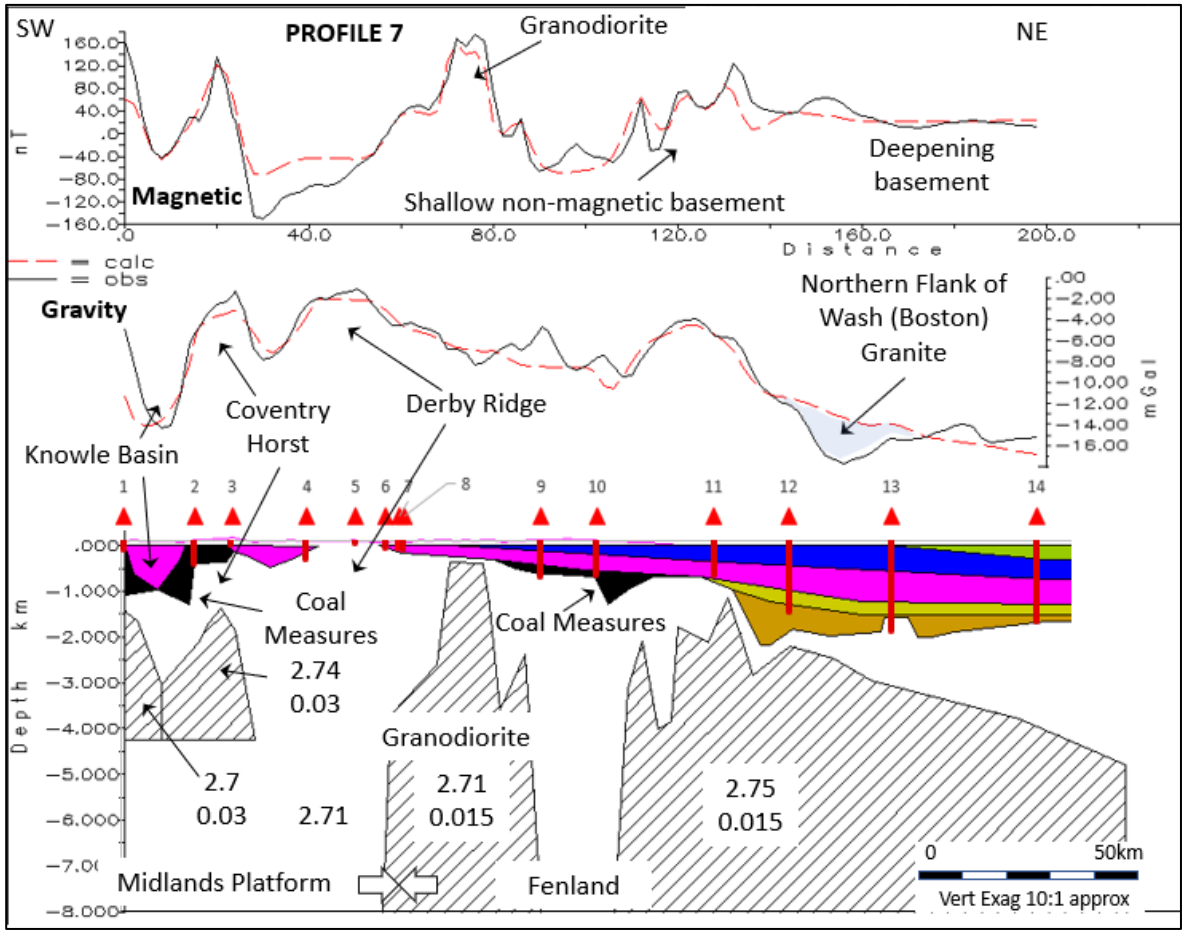
The profile begins over the southern edge of the Cleveland Basin. In this area, a thick Carboniferous sequence is developed which underwent inversion, initially in the Late Carboniferous and later in the Mesozoic and Tertiary (Doornenbal, H et al., 2010). A positive residual gravity anomaly at the northern end of the line is probably related to higher densities associated with the Cleveland Basin uplift, and assumed density values have been increased for the Basin to achieve agreement (see Figure 8 caption). South of the Fordon-1 well, the surface outcrop changes from Jurassic to Lower Cretaceous and then to a wide area of Upper Cretaceous Chalk further south. Although the profile intersects numerous wells, penetrations to the Lower Carboniferous section are limited until south of the Crawberry Hill borehole. Only the Welton-1 and Nocton-1 wells, towards the southern end of the profile, reach to pre-Lower Carboniferous sediments, therefore the thickness and lithology of the Lower Carboniferous is unclear over most of the profile. The presence of limestone facies in wells to the south, and the relatively undeformed characteristics of the section, suggest that the southern part of the profile is underlain by Lower Carboniferous platform carbonates. Above the carbonates are Upper Carboniferous sediments of the Namurian and Coal Measures which thin southwards from the North Dalton-1 well and outcrop, near the Crawberry Hill borehole, as the Yorkshire-Nottinghamshire Coal Basin. A large negative residual gravity anomaly develops in the vicinity of the Broomfleet-1, South Cliffe-1 and Crawberry Hill wells. This low is thought to be due to the presence of the Market Weighton Granite (Bott, et al., 1978). Further south, a Jurassic to Permian section overlies Upper Carboniferous and Lower Carboniferous shelf carbonates that in turn unconformably overlie Lower Paleozoic metasediments, as proved in the Welton-1 and Nocton-1 wells (Merriman R et al., 1993). The Acadian deformation event is thought to be the cause of this structural and metamorphic break. Magnetic anomalies have not been modelled as the profile runs along the strike of the Furness-Norfolk Magnetic Anomaly

| Profile 6 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 6 | 1 | Cloughton-1 | 499392 | 496802 | 0 | 2903.7 | U. Carb (Namurian) |
| 6 | 2 | Lockton East-1 | 493711 | 489826 | 9 | 1810.7 | U. Carb (Namurian) |
| 6 | 3 | Fordon-1 | 505834 | 475713 | 25.5 | 2173.1 | U. Carb (Namurian) |
| 6 | 4 | Langtoft-1 | 499340 | 465196 | 34.2 | 1852.5 | U. Carb (Westphalian) |
| 6 | 5 | Duggleby-1 | 488950 | 465050 | 37 | 2853.4 | U. Carb (Namurian) |
| 6 | 6 | North Dalton-1 | 493815 | 452770 | 47.8 | 1513.9 | U. Carb (U. Coal Measures) |
| 6 | 7 | Crawberry Hill BH | 487911 | 435220 | 61 | 2446 | Lower Carboniferous |
| 6 | 8 | South Cliffe-1 | 497670 | 437721 | 66.4 | 1059.4 | U. Carb (U. Coal Measures) |
| 6 | 9 | Broomfleet-1 | 489324 | 427706 | 74 | 1979.7 | Lower Carboniferous |
| 6 | 10 | Alkborough-1 | 488345 | 422644 | 79 | 1988 | Lower Carboniferous |
| 6 | 11 | Burton upon Strather-1 | 487865 | 418829 | 83 | 1793.7 | U. Carb (Namurian) |
| 6 | 12 | Broughton B 1 | 494627 | 410760 | 96.4 | 1851.8 | Lower Carboniferous |
| 6 | 13 | Glanford-1 | 501745 | 407278 | 99 | 1829.5 | Lower Carboniferous |
| 6 | 14 | Hibaldstow-1 | 498218 | 401211 | 104.4 | 1869.8 | Lower Carboniferous |
| 6 | 15 | Spital-1 | 496533 | 391145 | 114.6 | 1660.2 | Lower Carboniferous |
| 6 | 16 | West Firsby-1 | 498780 | 384578 | 121 | 1673.9 | U. Carb (Namurian) |
| 6 | 17 | Spridlington-1 | 501831 | 383813 | 123.7 | 1774.8 | U. Carb (Namurian) |
| 6 | 18 | Cold Hanworth-1 | 505391 | 382955 | 125 | 1745.8 | Lower Carboniferous |
| 6 | 19 | Dunholme-1 | 500853 | 379195 | 127.6 | 1619.3 | Lower Carboniferous |
| 6 | 20 | Welton-1 | 503612 | 376807 | 130.9 | 2536.7 | Sequence 1 (Camb-Trem) |
| 6 | 21 | Cherry Wilingham-1 | 504165 | 373273 | 134.5 | 1565.2 | Lower Carboniferous |
| 6 | 22 | Nocton-1 | 505109 | 364663 | 143.1 | 1153.7 | Sequence 1 (Camb-Trem) |

*Table 6 Profile 6 well data*

## Midlands Platform to Eastern England (Fenland and Anglian Basins)

**Profile 7 – Nechells Gas Works BH to 47/29a-1 – Southwest-Northeast orientation – Controlled by 14 wells**



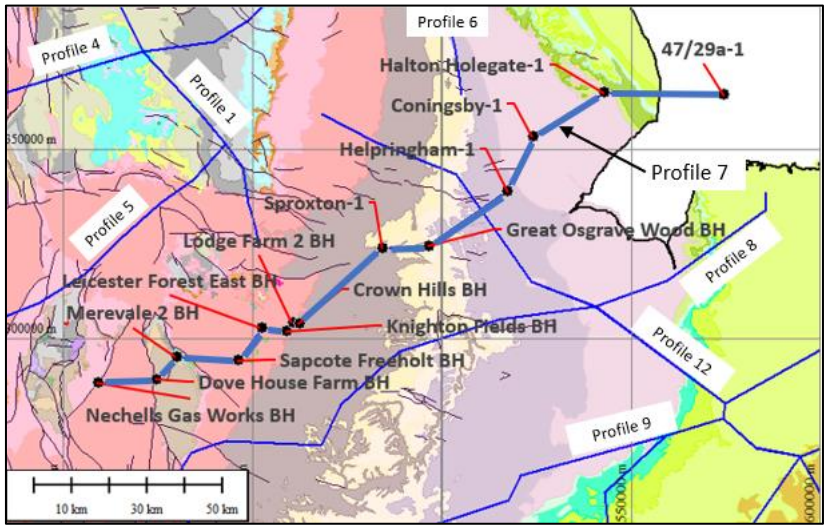




*Figure 10* ***Profile 7*** *Assumed densities are Cretaceous 2.2, Jurassic 2.35, Permo-Triassic 2.35/2.4, Westphalian 2.5, Namurian 2.5, Visean and Tournaisian 2.65, Igneous and Magnetic Basement as shown. The well locations are numbered as 1 Nechells Gas Works BH, 2 Dove House Farm BH, 3 Merevale 2 BH, 4 Sapcote Freeholt BH, 5 Leicester Forest East BH, 6 Knighton Fields BH, 7 Lodge Farm 2 BH, 8 Crown Hills BH, 9 Sproxton-1, 10 Great Osgrave Wood BH, 11 Helpringham-1, 12 Coningsby-1, 13 Halton Holegate-1 and 14 47/29a-1.*

**Profile 7 - Nechells Gas Works BH to 47/29a-1 – Southwest-Northeast orientation – Controlled by 14 wells**

The southwestern end of the profile crosses the northeastern margin of the Midlands Platform, a region marked by a series of north-south trending faults bounding basins in which thick Permo-Triassic sections are preserved. This includes the Knowle Basin in which the Permo-Triassic section produces a significant gravity low. This structuring gives rise to a rugose appearance to the top of the Lower Paleozoic structural surface. A local gravity anomaly is recognised between the Merevale 2 and Sapcote Freeholt boreholes and this has resulted from the presence of a thickened Permo-Triassic section (Bridge, et al., 1998), confirmed by the available seismic data (Allsop & Arthur , 1983). The eastern edge of the Midlands Platform, just to the west of the Leicester Forest East borehole, is thought to mark the western edge of Acadian deformation, with associated cleavage formation and enhanced maturity as compared to the Lower Paleozoic section of the Midlands Platform (Merriman R et al., 1993; Woodcock, 1991). A change in the basement is thought to lie to the east of the Crown Hills borehole, which marks the eastern limit of Ordovician Tremadocian shale occurrences seen in the wells. Further east in the Fenland Area, the wells show a complex picture of igneous intrusions, widespread indurated and deformed Cambrian and Ordovician metasediments, together with occurrences of Precambrian section. A pronounced magnetic anomaly exists between the Crown Hills borehole and the Sproxton-1 well. This has been interpreted as a granodiorite intrusion (Lee, et al., 1991). Seismic data confirms the presence of Carboniferous section preserved within grabens and faulted basins seen to the east of the Crown Hills borehole. Moving northeastwards, this complex geology is hidden beneath a structurally simple, progressively younger surface outcrop ranging from Triassic (beyond Merevale 2 borehole) to Jurassic (beyond Lodge Farm borehole) to Cretaceous (beyond Halton Holegate-1). A residual gravity low between Coningsby-1 and Halton Holegate-1 is thought to be due to the profile crossing the northern flank of the Boston Granite (Allsop, 1987).

| Profile 7 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 7 | 1 | Nechells Gas Works BH | 409330 | 288310 | 0 | 214 | U. Carb (U. Coal Measures) |
| 7 | 2 | Dove House Farm BH | 424740 | 289090 | 15.4 | 527.6 | Sequence 1 (Camb-Trem) |
| 7 | 3 | Merevale 2 BH | 430010 | 295090 | 23.5 | 86.6 | Sequence 1 (Camb-Trem) |
| 7 | 4 | Sapcote Freeholt BH | 446230 | 294310 | 39.7 | 397.8 | Sequence 1 (Camb-Trem) |
| 7 | 5 | Leicester Forest East BH | 452450 | 302830 | 50.2 | 74.7 | Sequence 1 (Camb-Trem) |
| 7 | 6 | Knighton Fields BH | 459220 | 301980 | 56.7 | 181.4 | Sequence 1 (Camb-Trem) |
| 7 | 7 | Lodge Farm 2 BH | 460820 | 304180 | 59.5 | 182.6 | Sequence 1 (Camb-Trem) |
| 7 | 8 | Crown Hills BH | 462450 | 303840 | 60.6 | 202.9 | Sequence 1 (Camb-Trem) |
| 7 | 9 | Sproxton-1 | 484510 | 323940 | 90.3 | 787.6 | Precambrian |
| 7 | 10 | Great Osgrave Wood BH | 496519 | 324600 | 102.4 | 753.4 | Precambrian |
| 7 | 11 | Helpringham-1 | 517530 | 338840 | 127.6 | 755.3 | U. Carb (Westphalian) |
| 7 | 12 | Coningsby-1 | 524142 | 353567 | 143.8 | 1530.3 | Lower Carboniferous |
| 7 | 13 | Halton Holegate-1 | 543061 | 365242 | 166 | 1942.1 | Sequence 2 (Ordovician) |
| 7 | 14 | 47/29a-1 | 574595 | 364612 | 197.4 | 1762 | Sequence 2 (Ordovician) |

*Table 7 Profile 7 well data*

**Profile 8 – West of Collington-1 to North Creake-1 – Southwest-Northeast orientation – Controlled by 17 wells**

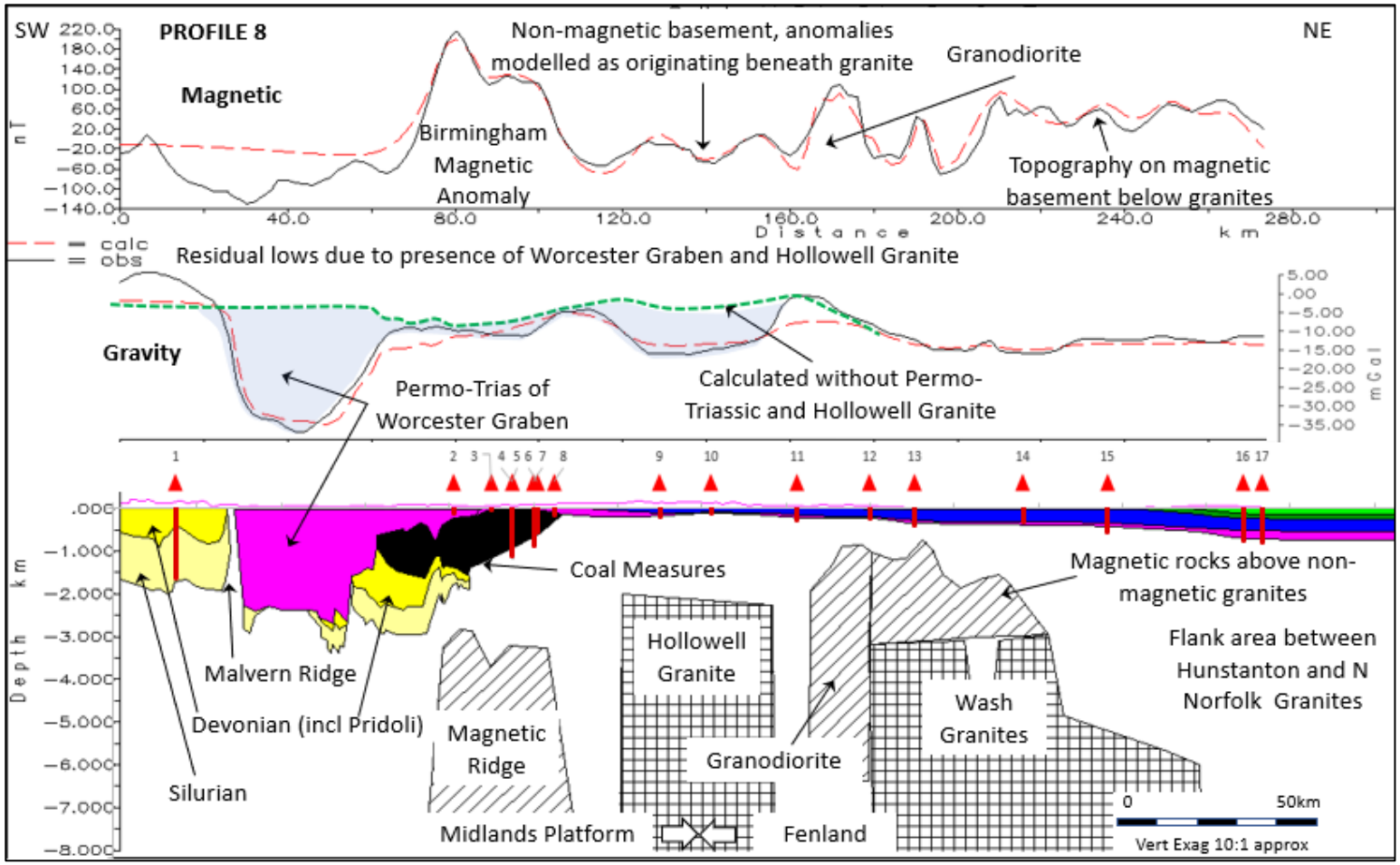
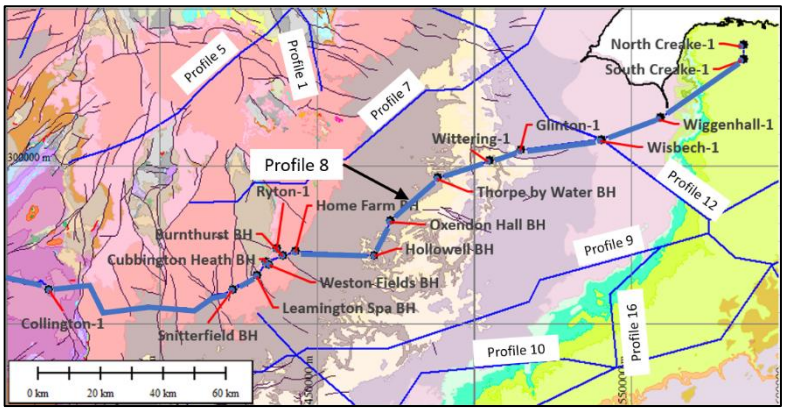



*Figure 11* ***Profile 8*** *Assumed densities are Upper Cretaceous 2.3, Lower Cretaceous 2.3, Jurassic 2.35, Permo-Triassic 2.41(Worcester Graben)/2.45, Coal Measures 2.6, Devonian and Silurian 2.72, Granites 2.67, Magnetic Rocks 2.72 Rem Mag 0.6SI 90°. The well locations are numbered as 1 Collington-1, 2 Snitterfield BH, 3 Leamington Spar BH, 4 Cubbington Heath BH, 5 Western Fields BH, 6 Burnthurst BH, 7 Ryton-1, 8 Home Farm BH, 9 Hollowell BH, 10 Oxendon Hall BH, 11 Thorpe by Water BH, 12 Wittering-1, 13 Glinton-1, 14 Wisbech-1, 15 Wiggenhall-1, 16 South Creake-1 and 17 North Creake-1*

**Profile 8 – West of Collington-1 to North Creake-1 – Southwest-Northeast orientation – Controlled by 17 wells**

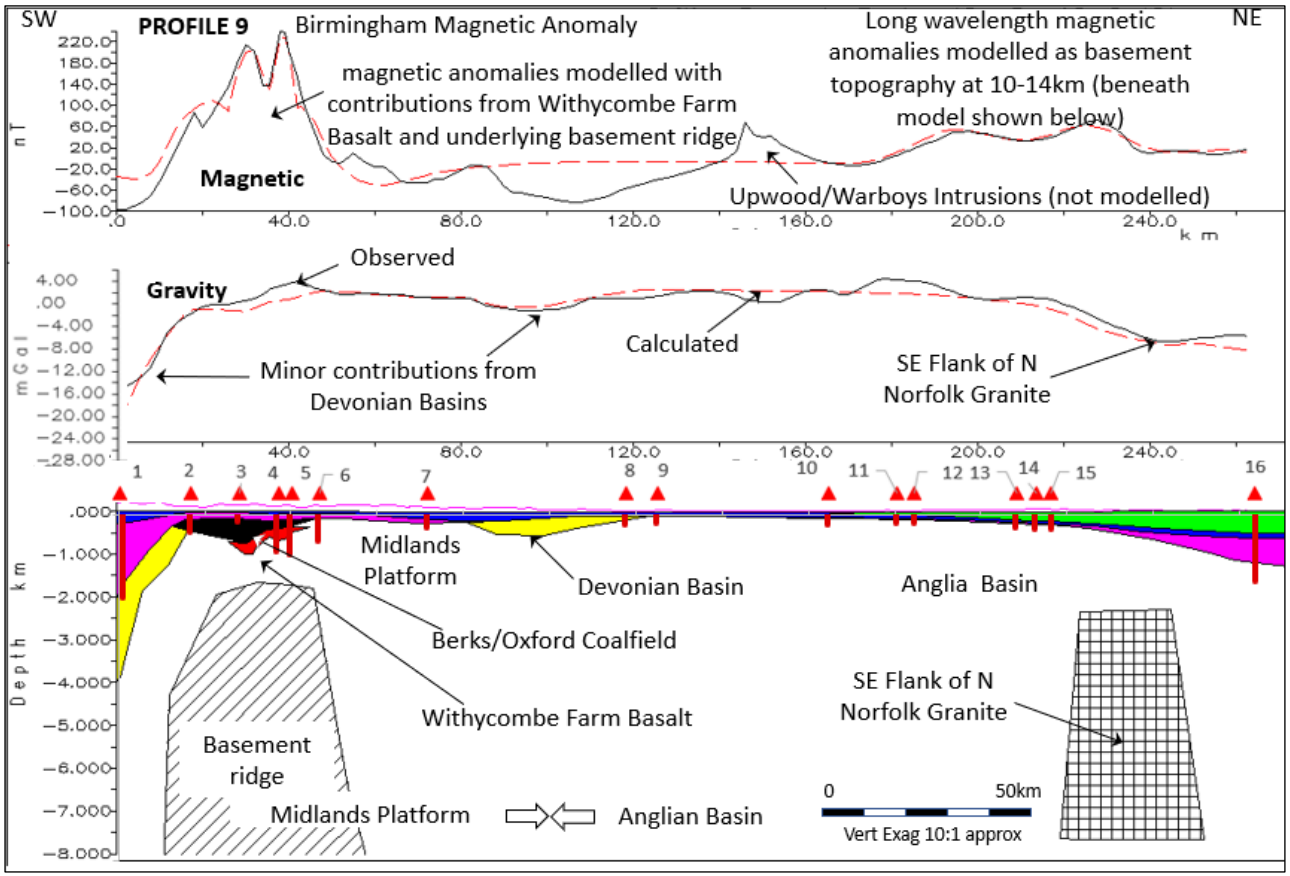



The detailed structure shown on the southwestern end of the profile over the Worcester Graben is based upon seismic interpretation (M Butler personal communication). In this area, the main contribution to the gravity anomaly appears to be the thick Permo-Triassic section of the Worcester Graben, with an additional contribution from the Upper Carboniferous Berkshire-Oxfordshire Coal Measures Basin. There appears to be only a minor contribution from the Devonian and Silurian sediments. East of the Worcester Graben, the line continues to cross the Midlands Platform with thin Mesozoic cover above the Coal Measures interval, which in turn overlies the relatively undeformed and unmetamorphosed Lower Paleozoic. Northeast of the Snitterfield borehole, the magnetic data suggest that magnetic basement is relatively shallow and a magnetic ridge is interpreted. This magnetic anomaly is part of the northwest to southeast trending Birmingham Magnetic Anomaly (BM of Figure 2(d)). Beyond the Cubbington Heath borehole, the Ordovician Tremadocian shales subcrop the Coal Measures (Old R et al., 1987) on a northerly extension of the Tamworth-Aylesbury structural high (Merriman R et al, 1993) The margin of the Midlands Platform in this area can be recognised in the magnetic data as an area of shallow non-magnetic basement. No effect is seen in the gravity data, which is dominated by an anomaly thought to be caused by the Hollowell Granite (Allsop, et al., 1987). To the east of the Hollowell borehole, a complex of deformed sediments and volcanics of Precambrian, Cambrian and Ordovician ages, of the Fenland Area, have been proven by wells. Based on the gravity and magnetics data, a series of intrusions thought to be granodiorites and granites are interpreted. Further to the east, Triassic outcrop gives way to a thick Jurassic (beyond Cubbington Heath borehole), giving way to the Cretaceous (beyond Wiggenhall borehole).

| Profile 8 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 8 | 1 | Collington-1 | 364630 | 261000 | 15 | 1597.7 | Precambrian |
| 8 | 2 | Snitterfield BH | 423210 | 260850 | 81 | 115.8 | U. Carb (U. Coal Measures) |
| 8 | 3 | Leamington Spa BH | 430920 | 265390 | 90 | 56.3 | U. Carb (U. Coal Measures) |
| 8 | 4 | Cubbington Heath BH | 433797 | 269761 | 95 | 1143.6 | U. Carb (U. Coal Measures) |
| 8 | 5 | Weston Fields BH | 434834 | 268899 | 95 | 1075.3 | Sequence 1 (Camb-Trem) |
| 8 | 6 | Burnthurst BH | 439185 | 271701 | 101 | 554.4 | Sequence 1 (Camb-Trem) |
| 8 | 7 | Ryton-1 | 437310 | 273970 | 100 | 838.4 | Sequence 1 (Camb-Trem) |
| 8 | 8 | Home Farm BH | 443170 | 273090 | 105 | 150.9 | Sequence 1 (Camb-Trem) |
| 8 | 9 | Hollowell BH | 468331 | 271832 | 130 | 193.8 | Precambrian |
| 8 | 10 | Oxendon Hall BH | 473430 | 282750 | 142.3 | 129.5 | Precambrian |
| 8 | 11 | Thorpe by Water BH | 488570 | 296480 | 162.8 | 266 | Ordovician |
| 8 | 12 | Wittering-1 | 504920 | 301845 | 180 | 246.6 | Precambrian |
| 8 | 13 | Glinton-1 | 515020 | 305260 | 190.7 | 377.9 | Precambrian |
| 8 | 14 | Wisbech-1 | 540660 | 308425 | 216.4 | 320.9 | Ordovician |
| 8 | 15 | Wiggenhall-1 | 559410 | 315370 | 236.5 | 557.8 | Ordovician |
| 8 | 16 | South Creake-1 | 585730 | 334019 | 268.7 | 730.6 | Silurian |
| 8 | 17 | North Creake-1 | 585660 | 338630 | 273.3 | 780.6 | Ordovician |

*Table 8 Profile 8 well data*

**Profile 9 - Guiting Power-1 to Bacton-2 – Southwest-Northeast orientation – Controlled by 16 wells**



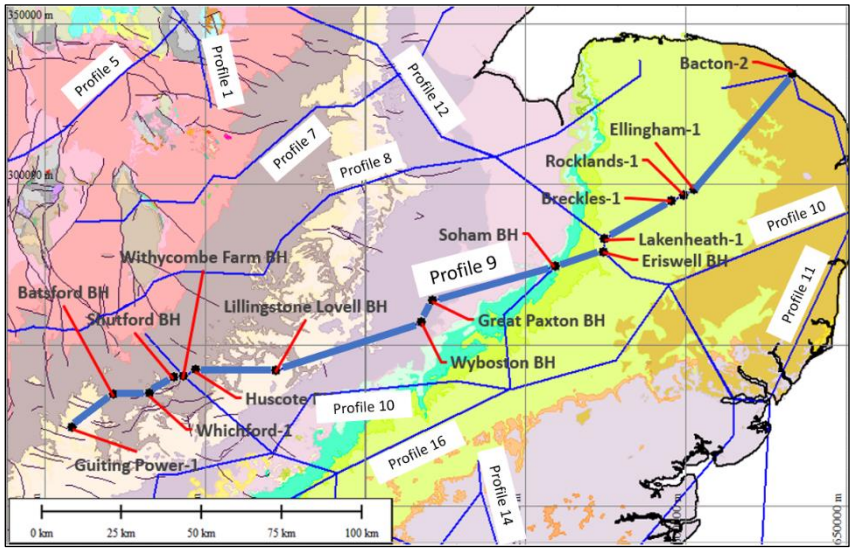




*Figure 12* ***Profile 9*** *Assumed densities are Cretaceous 2.3, Jurassic 2.35, Permo-Triassic 2.45, Coal Measures 2.55. Devonian 2.5 2.55(SW), Granite 2.66 (2km Half Strike, profile on SE Flank), Basement Ridge 2.72, 0.7SI 90°, Withycombe Farm basalt 2.8, 3.5SI 90°, Deep Magnetic basement 2.72, 0.03SI 90° (base at 14km). A background density of 2.72 has been assumed. The well locations are numbered as 1 Guiting Power-1, 2 Batsford BH, 3 Whichford-1, 4 Shutford BH, 5 Withycombe Farm BH, 6 Huscote BH, 7 Lillingstone Lovell BH, 8 Wyboston BH, 9 Great Paxton BH, 10 Soham BH, 11 Eriswell BH, 12 Lakenheath-1, 13 Breckles-1, 14 Rocklands-1, 15 Ellingham-1, 16 Bacton-2*

**Profile 9 - Guiting Power-1 to Bacton-2 – Southwest-Northeast orientation – Controlled by 16 wells**

The southwestern end of the profile crosses the Midlands Platform. In this area, a thick Devonian section underlies the Coal Measures of the Oxfordshire - Berkshire Coalfield. The Devonian basin, here called the Wantage Basin, is truncated to the northeast before the older subcrop of Silurian section, as seen at the Batsford borehole. Moving to the northeast, the older Ordovician Tremadocian rocks, associated with the Tamworth-Aylesbury High, initially subcrop the Coal Measures but subcrop the Triassic at the Lillingstone Lovell borehole (Molyneux, 1991). The magnetic data suggest contributions from both shallow and deep sources. The deeper source may relate to a basement ridge at a depth of approximately 2 km (Busby, et al., 2006) in the vicinity of the Shutford and Whichford boreholes. The Birmingham Magnetic Anomaly lies slightly offset to the southwest of the area where the Precambrian is interpreted to be structurally shallowest. Our work suggests a magnetic source within the Precambrian, this is in line with the suggestion of it being due to the plutonic core of a Neoproterozoic (Charnian) arc, as suggested by Lee (Lee, et al., 1990; Busby, et al., 1993). However, the effects of younger, shallower volcanics are also seen, probably associated with the Withycombe Farm Precambrian basalt with possibly additional contributions from Carboniferous volcanics. Jurassic rocks outcrop at the surface over this area of the profile. The eastern margin of the Midlands Platform is thought to represent the western edge of intense Acadian deformation, based on maturity and structural data (Merriman R et al, 1993; Woodcock, 1991), and lies just to the east of the Lillingstone Lovell borehole. This edge appears to be coincident with the western edge of the Luton/Cambridge Basin (Allsop, 1985), thought to have a Devonian fill. The centre of this basin is undrilled and therefore the nature and thickness of the fill are unproven. The magnetic basement deepens significantly across this edge into the Anglian Basin and the bland signature of the magnetic data suggests the absence of intrusions or volcanics. The Lower Paleozoic subcrop, beneath the Mesozoic, youngs from the Ordovician Tremadocian (at Wyboston) to Ordovician Llanvirn (at Great Paxton) before Silurian rocks are encountered in the Soham borehole. A short wavelength magnetic anomaly occurs between the Great Paxton-1 well and the Soham borehole. This is thought to be associated with the Upwood/Warboys diorite intrusions (Allsop, 1985). The Silurian subcrop continues to the east before Ordovician section again subcrops, beneath the Mesozoic and Permian, as proved by the Bacton-2 well. At the surface, the outcrop of Jurassic sediments is overlain by Upper Cretaceous rocks near to the Soham borehole. The Mesozoic and Permian section thickens, and the top Carboniferous deepens, towards the coast as the Southern North Sea Permian Basin is approached.

| Profile 9 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 9 | 1 | Guiting Power-1 | 408550 | 224510 | 0 | 1934 | Upper Devonian |
| 9 | 2 | Batsford BH | 421500 | 234700 | 16.5 | 402 | Silurian |
| 9 | 3 | Whichford-1 | 432660 | 234889 | 27.6 | 177 | U. Carb (U. Coal Measures) |
| 9 | 4 | Shutford BH | 440110 | 239970 | 36.7 | 849 | Upper Devonian |
| 9 | 5 | Withycombe Farm BH | 443190 | 240170 | 39.8 | 921 | Precambrian |
| 9 | 6 | Huscote BH | 446891 | 242422 | 46.2 | 611 | Sequence 1 (Camb-Trem) |
| 9 | 7 | Lillingstone Lovell BH | 471969 | 241972 | 71.3 | 299 | Sequence 1 (Camb-Trem) |
| 9 | 8 | Wyboston BH | 517590 | 257230 | 117.3 | 220 | Sequence 1 (Camb-Trem) |
| 9 | 9 | Great Paxton BH | 520880 | 263890 | 124.7 | 178 | Ordovician |
| 9 | 10 | Soham BH | 559250 | 274470 | 164.5 | 237 | Silurian |
| 9 | 11 | Eriswell BH | 574250 | 278860 | 180.2 | 197 | Silurian |
| 9 | 12 | Lakenheath-1 | 574800 | 283000 | 184.3 | 209 | Silurian |
| 9 | 13 | Breckles-1 | 595510 | 294690 | 208.1 | 291 | Silurian |
| 9 | 14 | Rocklands-1 | 599520 | 296700 | 212.6 | 318 | Silurian |
| 9 | 15 | Ellingham-1 | 602620 | 298470 | 216.2 | 337 | Silurian |
| 9 | 16 | Bacton-2 | 633386 | 334458 | 263.5 | 1524 | Ordovician |

*Table 9 Profile 9 well data*

**Profile 10 - Cooles Farm-1 to Lowestoft BH– Southwest - Northeast – Controlled by 16 wells**

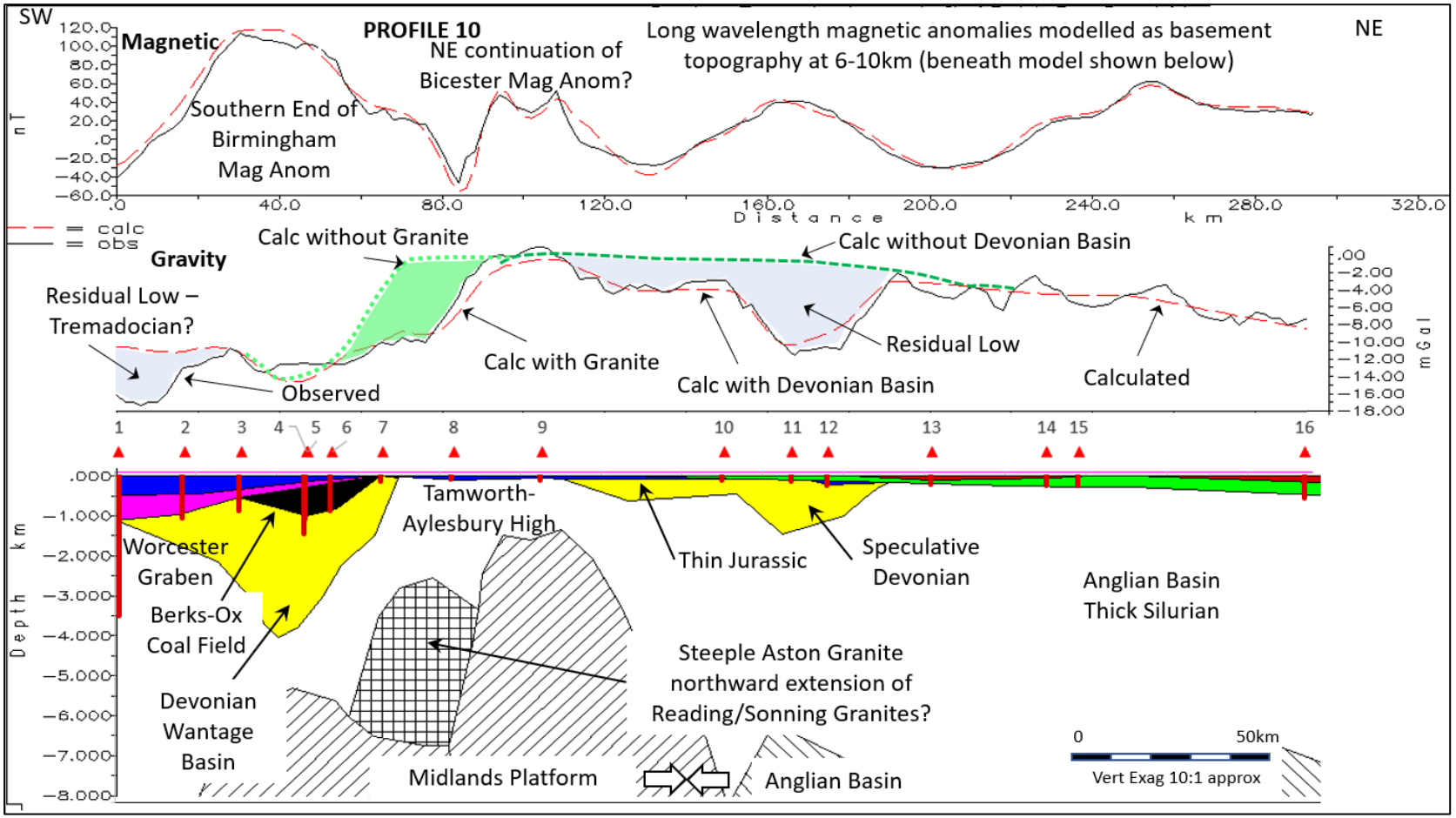
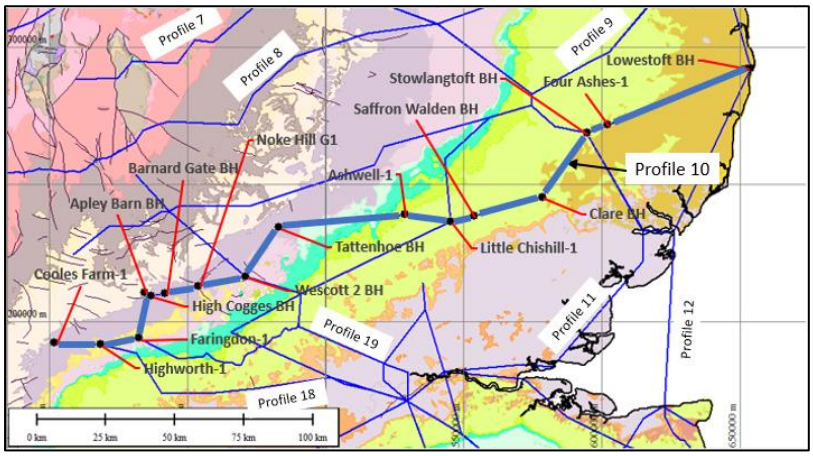



*Figure 13* ***Profile 10*** *Assumed densities are Tertiary 2.25, Cretaceous 2.3, Jurassic 2.6, Permo-Triassic 2.44, Coal Measures 2.55, Devonian 2.55 and 2.65 for deep basin, Granite 2.65, Basement Ridge 2.72, 0.04 SI (W) 0.02 SI (E). A background density of 2.72 has been assumed. The well locations are numbered as 1 Cooles Farm-1, 2 Highworth-1, 3 Faringdon-1, 4 Apley Barn BH, 5 High Coggles BH, 6 Barnard Gate BH, 7 Noke Hill G1, 8 Wescott 2 BH, 9 Tattenhoe BH, 10 Ashwell-1, 11 Little Chishill-1, 12 Saffron Walden BH, 13 Clare BH, 14 Stowlangtoft BH, 15 Four Ashes-1, and 16 Lowestoft BH.*

**Profile 10 - Cooles Farm-1 to Lowestoft BH– Southwest - Northeast – Controlled by 16 wells**




The profile begins in the west within the Worcester Graben where thick Jurassic and Permo-Triassic section overlies thick Tremadocian rocks, penetrated by the Cooles Farm well (Molyneux, 2010a; Shell, 1975). To the east, the profile crosses the eastern margin of the Worcester Graben, where a thick Devonian sequence is developed. Seismic data demonstrate that a Silurian sequence conformably underlies the Devonian but unconformably overlies the Ordovician Tremadocian sequence. The Upper Carboniferous coal-bearing sequence of the Berkshire-Oxfordshire Coalfield overlies a thick Devonian section (Butler, 2018), here called the Wantage Basin (see Profile 17). The profile crosses the southern end of the Birmingham Magnetic Anomaly, with an additional magnetic high (between 80 and 120km) possibly related to the northeasterly continuation of the magnetic anomaly associated with the Silurian volcanics in the Bicester well. The Paleozoic section rises and is truncated on the flanks of the Tamworth-Aylesbury High by erosion and truncation below the Mesozoic, but also possibly by pinch out. Gravity data over the High suggest that it may include a granitic intrusion, named as the Steeple Aston Granite, possibly a northerly extension of the Reading/Sonning granite trend. Here, the Ordovician Tremadocian section subcrops directly the Jurassic, the Triassic having pinched out and been overlapped on the flanks of the High. Further east, a negative residual gravity anomaly is recognised below the Jurassic and Cretaceous cover, which is thought to be caused by a basinal sequence with Devonian fill (the Luton/Cambridge Basin (Allsop, 1985), see profile 9). This basin is thought to straddle the eastern margin of the Midlands Platform, defined on the magnetic data which shows a significant deepening to the east into the Anglian Basin. Within the Anglian Basin, a thick Silurian sequence subcrops the Cretaceous. Since all the wells confirm a consistent Silurian subcrop, the variations in the gravity response suggest thickness changes and/or lateral variations in the density of the Silurian interval.

| Profile 10 | Well No | Well Name | X | Y | Distance Along Profile | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 10 | 1 | Cooles Farm-1 | 401641 | 192135 | 0 | 3418 | Sequence 1 (Camb-Trem) |
| 10 | 2 | Highworth-1 | 418314 | 191528 | 16.5 | 1057 | Silurian |
| 10 | 3 | Faringdon-1 | 432240 | 193980 | 30.5 | 863.5 | Upper Devonian |
| 10 | 4 | Apley Barn BH | 434380 | 210660 | 46.5 | 1421.3 | Lower Devonian |
| 10 | 5 | High Cogges BH | 436670 | 209218 | 47 | 1067.2 | U. Carb (U. Coal Measures) |
| 10 | 6 | Barnard Gate BH | 441688 | 210205 | 53 | 874 | Upper Devonian |
| 10 | 7 | Noke Hill G1 | 453870 | 212861 | 65.5 | 151.8 | Upper Devonian |
| 10 | 8 | Wescott 2 BH | 470960 | 216490 | 83 | 95.6 | Sequence 1 (Camb-Trem) |
| 10 | 9 | Tattenhoe BH | 482890 | 234370 | 105 | 110.8 | Sequence 1 (Camb-Trem) |
| 10 | 10 | Ashwell-1 | 528600 | 239000 | 150 | 124.7 | Upper Devonian |
| 10 | 11 | Little Chishill-1 | 545280 | 236370 | 167 | 153.6 | Lower Devonian |
| 10 | 12 | Saffron Walden BH | 553860 | 238400 | 176 | 256.9 | Lower Devonian |
| 10 | 13 | Clare BH | 578380 | 245370 | 201.5 | 222.7 | Silurian |
| 10 | 14 | Stowlangtoft BH | 594750 | 268820 | 230 | 257.6 | Silurian |
| 10 | 15 | Four Ashes-1 | 602230 | 271860 | 238 | 238.4 | Silurian |
| 10 | 16 | Lowestoft BH | 653830 | 292590 | 294 | 554.7 | Silurian |

*Table 10 Profile 10 well data*

**Profile 11 - Strat A1 to Saxthorpe-1 – Southwest-Northeast to Lowestoft, then Northwest to Saxthorpe-1 – Controlled by 13 wells**

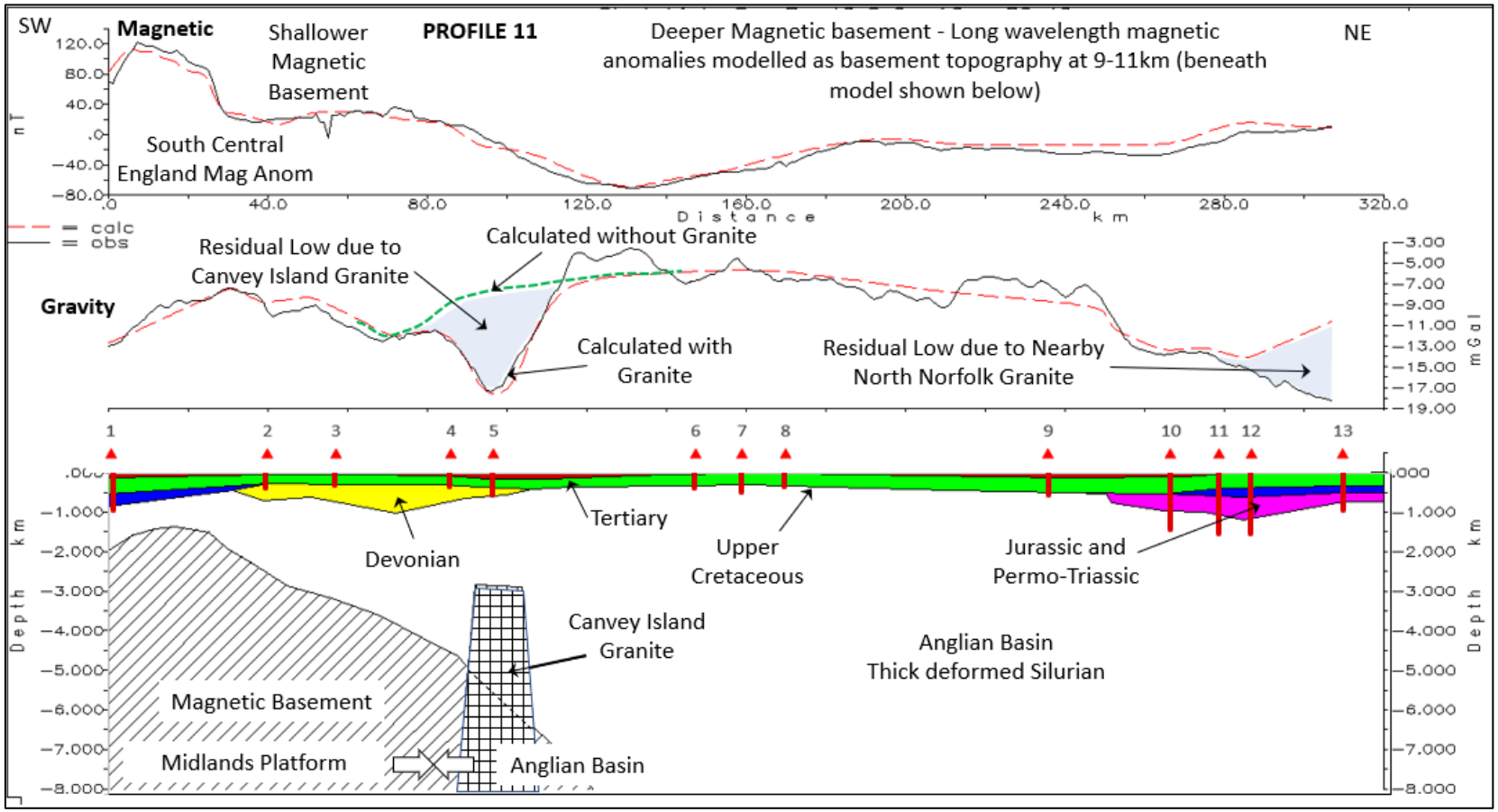
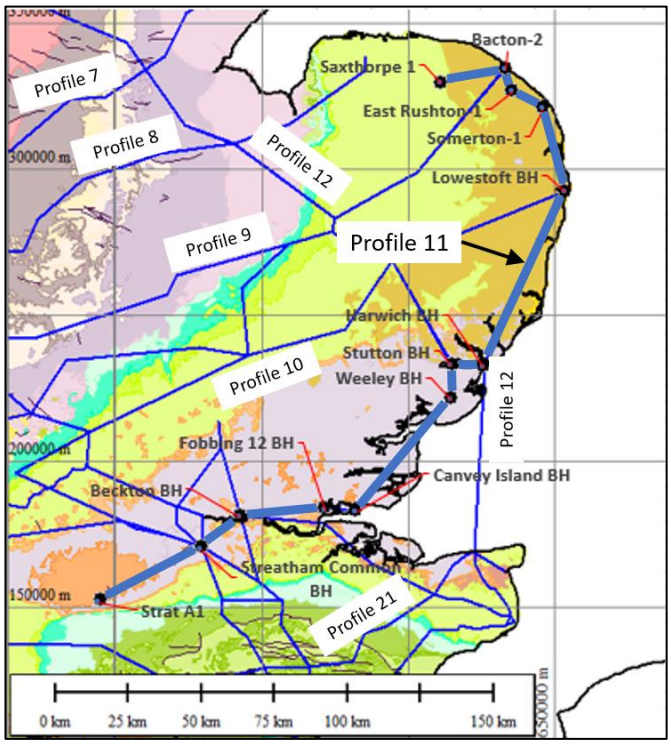



*Figure 14* ***Profile 11*** *Assumed densities are Tertiary 2.3, Cretaceous 2.3, Jurassic 2.45, Permo-Triassic 2.5, Devonian 2.5, Granite 2.66, Basement Ridge 2.72, 0.04 SI. A background density of 2.72 has been assumed. The well locations are numbered as 1 Strat A1, 2 Streatham Common BH, 3 Beckton BH, 4 Fobbing 12 BH, 5 Canvey Island BH, 6 Weeley BH, 7 Stutton BH, 8 Harwich BH, 9 Lowestoft BH, 10 Somerton-1, 11 East Rushton-1, 12 Bacton-2, and 13 Saxthorpe-1.*

**Profile 11 - Strat A1 to Saxthorpe-1 – Southwest-Northeast to Lowestoft, then Northwest to Saxthorpe-1 – Controlled by 13 wells**




The western end of the profile is on the edge of the Warlingham residual gravity anomaly. Here, Upper Cretaceous and Jurassic sequences overlie deformed Lower Ordovician aged sediments in the Strat A1 well (DTI, 2006). The profile runs along the north side of the anomaly, encountering Lower Devonian sediments in the Streatham Common, Beckton, and Canvey Island boreholes (Smart J et al., 1964; Molyneux, 1991). Common to all of these wells, the sequences show the effect of deformation thought to be due to the Variscan Orogeny. At the surface, Tertiary beds of the London Basin overlie the Upper Cretaceous sediments that directly overlie the deformed Devonian. The northeastern margin of the Midlands Platform is coincident with a small, circular gravity anomaly thought to be due to the presence of a granite near Canvey Island (Rabae & Kearey, 1997) (see Profile 13). Further northeast, subcropping the Mesozoic, are deformed Silurian sediments of the Anglian Basin that extend as far as the Somerton-1 well with Ordovician sediments in the Bacton-2 well. North of the Lowestoft borehole, the Mesozoic and Permian section thickens, and the top Paleozoic deepens towards the Southern North Sea Permian Basin. The gravity anomaly at the end of the profile is thought to show the proximity of a buried granite in North Norfolk (Chronston, et al., 1987).

| Profile 11 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 11 | 1 | Strat A1 | 494780 | 152780 | 0 | 921.1 | Silurian |
| 11 | 2 | Streatham Common BH | 529560 | 170980 | 39.2 | 353.9 | Lower Devonian |
| 11 | 3 | Beckton BH | 542800 | 181650 | 56.3 | 306.9 | Lower Devonian |
| 11 | 4 | Fobbing 12 BH | 571500 | 184200 | 85.1 | 331.9 | Lower Devonian |
| 11 | 5 | Canvey Island BH | 582150 | 183300 | 95.8 | 529.5 | Lower Devonian |
| 11 | 6 | Weeley BH | 614720 | 221840 | 146.2 | 359.4 | Silurian |
| 11 | 7 | Stutton BH | 615000 | 233400 | 157.8 | 464 | Silurian |
| 11 | 8 | Harwich BH | 625930 | 232780 | 168.7 | 331.6 | Silurian |
| 11 | 9 | Lowestoft BH | 653830 | 292590 | 234.4 | 554.7 | Silurian |
| 11 | 10 | Somerton-1 | 646071 | 321202 | 265 | 1396.6 | Silurian |
| 11 | 11 | East Rushton-1 | 635358 | 326814 | 277 | 1522.7 | Lower Carboniferous |
| 11 | 12 | Bacton-2 | 633386 | 334458 | 285 | 1523.6 | Ordovician |
| 11 | 13 | Saxthorpe 1 | 611109 | 329778 | 308 | 938.1 | Silurian |

*Table 11 Profile 11 well data*

## Eastern England (Fenland/Anglian Basin) to Southern England

### Profile 12 – Eakring-146 to Harwich BH to Bere Farm BH – Northwest-Southeast – Controlled by 24 wells

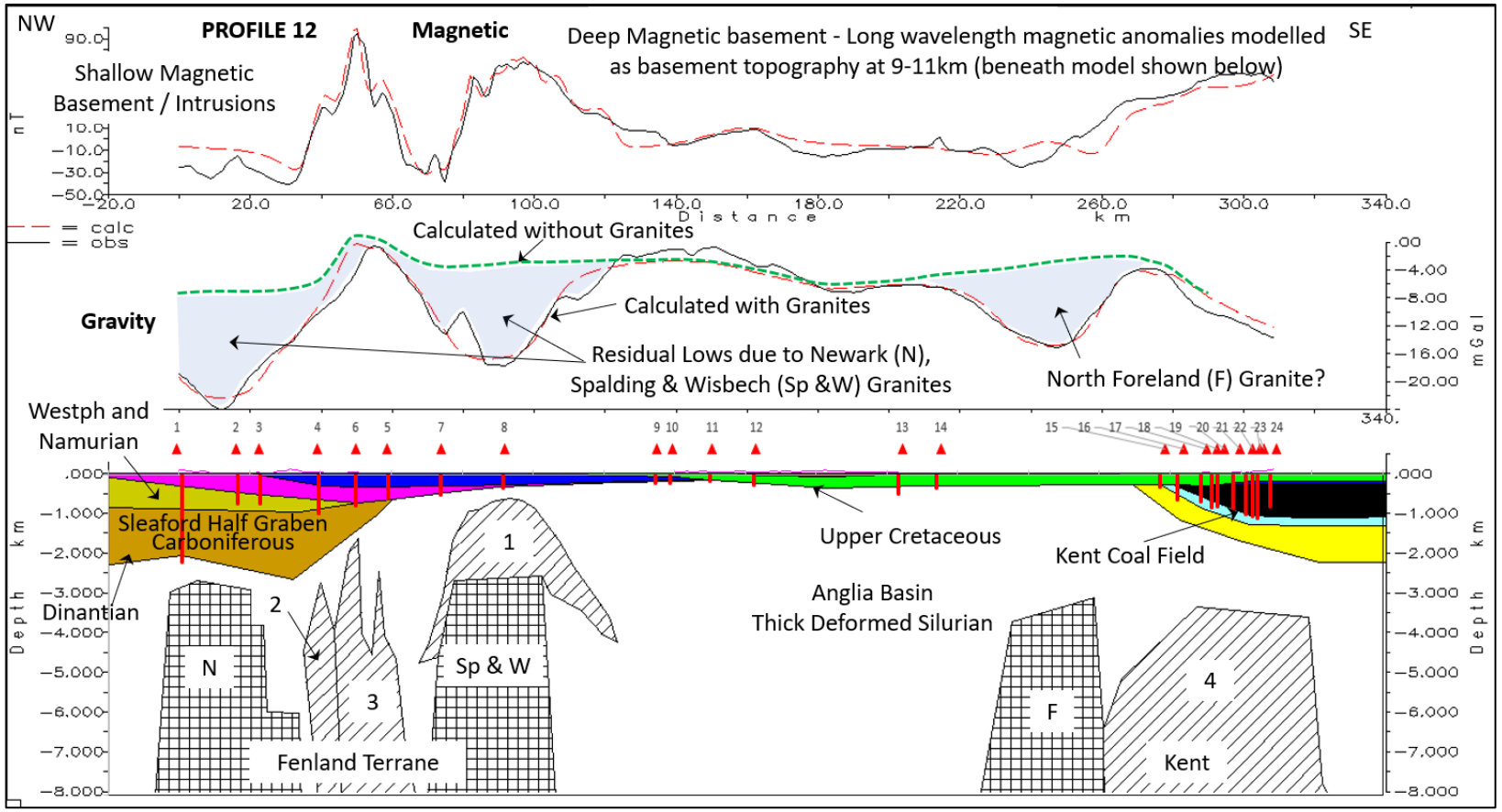
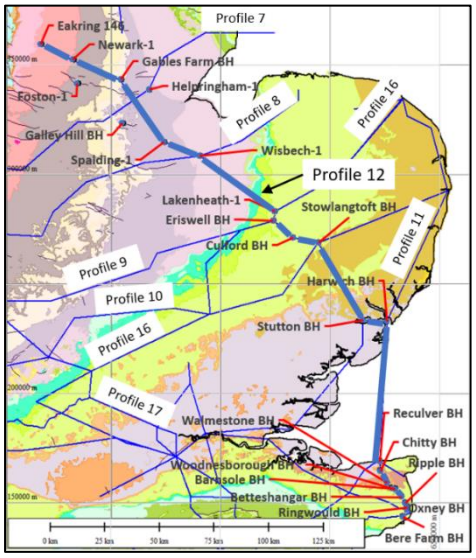



*Figure 15* ***Profile 12*** *Assumed densities are Tertiary 2.2, Cretaceous 2.3, Jurassic 2.5, Permo-Triassic 2.5, Coal Measures 2.45, Westphalian and Namurian (Sleaford Graben) 2.55, Dinantian (Lmst) 2.72, Dinantian (Sleaford Graben) 2.7, Devonian 2.6, Newark Granite 2.65, Spalding/Wisbech of Wash Granites 2.66, North Foreland Granite? 2.67, Basement/Intrusion1 2.72 1.0SI 90°, Basement/Intrusion2 2.72 0.38SI 90°, Basement/Intrusion3 2.78 0.38SI 90°, Basement4 2.73, 0.4SI 90°. A background density of 2.72 has been assumed. The well locations are numbered as 1 Eakring-146, 2 Newark-1, 3 Foston-1 (offset), 4 Gables Farm BH, 5 Galley Hill BH (offset), 6 Helpringham-1 (offset), 7 Spalding-1, 8 Wisbech-1, 9 Lakenheath-1, 10 Eriswell BH, 11 Culford BH, 12 Stowlangtoft BH, 13 Stutton BH, 14 Harwich BH, 15 Reculver BH, 16 Chitty BH, 17 Walmestone BH, 18 Barnsole BH, 19 Woodnesborough BH, 20 Betteshanger BH, 21 Ripple BH, 22 Ringwould BH, 23 Oxney BH and 24 Bere Farm BH.*

**Profile 12 – Eakring-146 to Harwich BH to Bere Farm BH – Northwest-Southeast – Controlled by 24 wells**

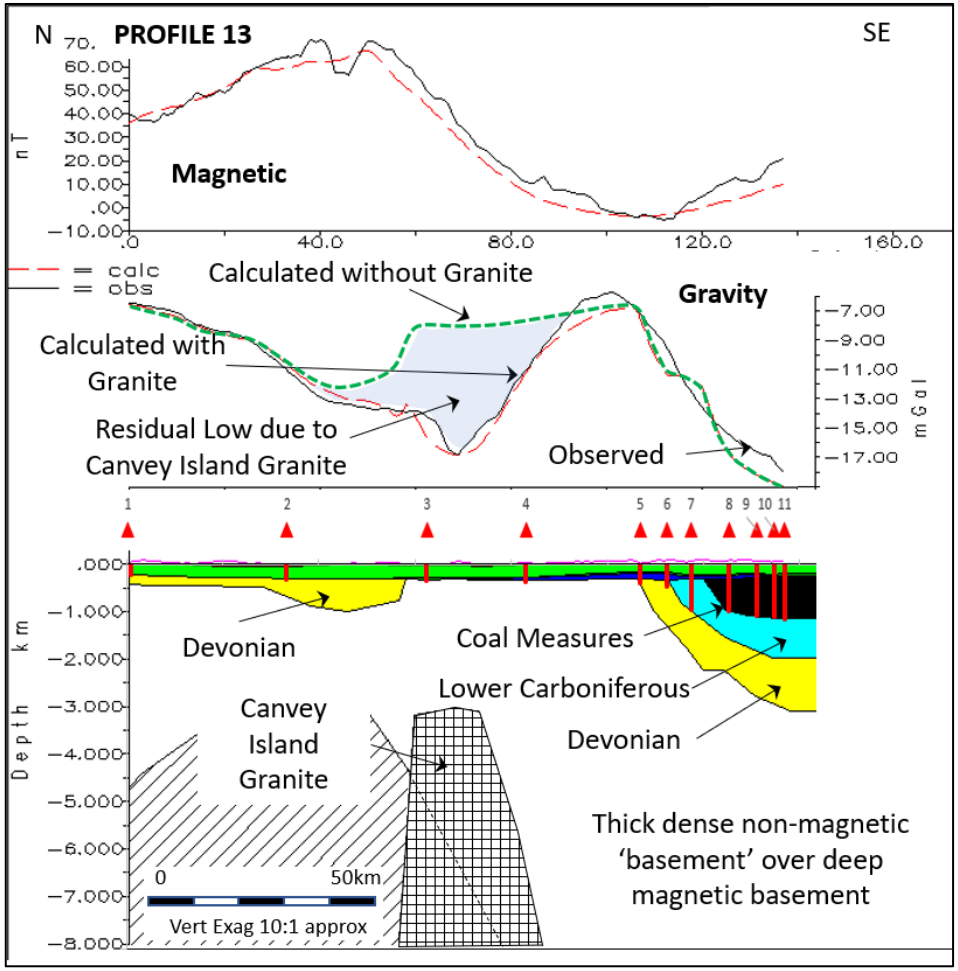
At the northern end of the profile, Triassic rocks outcrop and unconformably overlie a faulted Carboniferous section that pinches out northwest of the Spalding-1 well. Below the Carboniferous section, the well data indicate the presence of deformed Ordovician and Precambrian metasediments with associated volcanics. The presence of Cambrian sediments has also been suggested based on lithostratigraphic grounds, but the intervals are undated and have been metamorphosed and deformed making identification difficult. A granite intrusion is thought to have resulted in the low gravity anomaly recognised near Newark-1 (Allsop, 1987 and Donato, 2019). Further south, near the Spalding and Wisbech wells, a series of residual low gravity anomalies are also thought to be caused by granites (Allsop, 1987). A change in magnetic character occurs along the profile, with the higher amplitude and shorter wavelength magnetic anomalies north of Wisbech-1 being replaced by a more quiescent, and probably deeply-sourced, series of weak anomalies that characterises the Anglian Basin. This is thought to be caused by the absence of igneous intrusions or volcanics within the section south of Wisbech-1 and by an associated deepening of magnetic basement. Also, south of the Wisbech-1 well, the well data reveal a change in the Mesozoic subcrop from Ordovician and older metasediments and igneous rocks to a Silurian section which is less deformed and metamorphosed (Molyneux, 1991; Merriman R et al., 1993). At the surface in the same area, Upper Cretaceous section outcrops, dipping to the southeast towards the London Basin, where Tertiary section is preserved. The deeper Triassic and Jurassic intervals pinch out south of the Eriswell borehole, against a palaeohigh thought to have a Variscan origin. Offshore, south of the Harwich borehole, a large gravity anomaly exists. This anomaly may reflect the existence of a granite located nearby, labelled North Foreland Granite on the profile (Rabae & Kearey, 1997), or the presence of a sedimentary basin with Paleozoic fill. Onshore in Kent, an Upper Paleozoic basin is developed containing the Upper Carboniferous, Westphalian-aged Coal Measures of the Kent Coalfield, with underlying Lower Carboniferous, Devonian and Lower Paleozoic sediments.



| Profile 12 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 12 | 1 | Eakring 146 | 468073 | 359484 | 0 | 2174.3 | Sequence 1 (Camb-Trem) |
| 12 | 2 | Newark-1 | 482900 | 352440 | 16.5 | 725 | Lower Carboniferous |
| 12 | 3 | Foston-1 | 484894 | 341459 | 23 | 719.9 | Sequence 1 (Camb-Trem) |
| 12 | 4 | Gables Farm BH | 504590 | 343280 | 39.4 | 974.1 | Lower Carboniferous |
| 12 | 5 | Galley Hill BH | 505454 | 323314 | 59 | 583 | Sequence 1 (Camb-Trem) |
| 12 | 6 | Helpringham-1 | 517530 | 338840 | 50 | 755.3 | U. Carb (Westphalian) |
| 12 | 7 | Spalding-1 | 524345 | 314782 | 74 | 496.2 | Sequence 1 (Camb-Trem) |
| 12 | 8 | Wisbech-1 | 540660 | 308425 | 91.7 | 320.9 | Ordovician |
| 12 | 9 | Lakenheath-1 | 574800 | 283000 | 134.5 | 209.4 | Silurian |
| 12 | 10 | Eriswell BH | 574250 | 278860 | 138.7 | 197.1 | Silurian |
| 12 | 11 | Culford BH | 583100 | 271070 | 150 | 166.7 | Silurian |
| 12 | 12 | Stowlangtoft BH | 594750 | 268820 | 162.3 | 257.6 | Silurian |
| 12 | 13 | Stutton BH | 615000 | 233400 | 203.2 | 464 | Silurian |
| 12 | 14 | Harwich BH | 625930 | 232780 | 214 | 331.6 | Silurian |
| 12 | 15 | Reculver BH | 622680 | 169000 | 277 | 310.6 | Lower Devonian |
| 12 | 16 | Chitty BH | 623120 | 164770 | 282.2 | 612.6 | Lower Devonian |
| 12 | 17 | Walmestone BH | 626000 | 159230 | 288.6 | 674.2 | U. Carb (U. Coal Measures) |
| 12 | 18 | Barnsole BH | 628246 | 156781 | 291.6 | 816.1 | Lower Carboniferous |
| 12 | 19 | Woodnesborough BH | 629780 | 156480 | 293.4 | 786.4 | Lower Carboniferous |
| 12 | 20 | Betteshanger BH | 632640 | 152930 | 297.9 | 864.1 | U. Carb (U. Coal Measures) |
| 12 | 21 | Ripple BH | 634330 | 149980 | 301.4 | 990.3 | Lower Carboniferous |
| 12 | 22 | Ringwould BH | 635290 | 148120 | 303.4 | 1030.7 | Lower Carboniferous |
| 12 | 23 | Oxney BH | 635220 | 146950 | 304.7 | 1094.5 | U. Carb (U. Coal Measures) |
| 12 | 24 | Bere Farm BH | 633360 | 143840 | 308.2 | 795.2 | U. Carb (U. Coal Measures) |

*Table 12 Profile 12 well data*

**Profile 13 - Ware BH to St Margarets BH – North-Southeast orientation – Controlled by 11 wells**



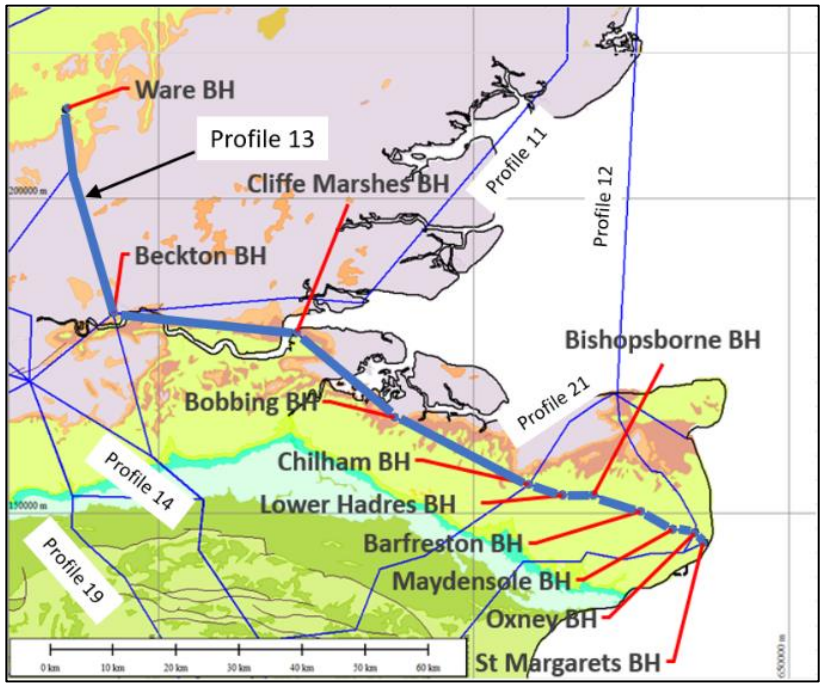




*Figure 16* ***Profile 13*** *Assumed densities are Tertiary 1.95, Upper Cretaceous 2.1, Lower Cretaceous 2.3, Jurassic 2.4, Coal Measures 2.5, Devonian 2.55/2.6(SE), Granite 2.66, Deep Magnetic basement 2.72, 0.015 SI 90°. A background density of 2.72 has been assumed. The well locations are numbered as 1 Ware BH, 2 Beckton BH, 3 Cliffe Marshes BH, 4 Bobbing BH, 5 Chilham BH, 6 Lower Hardres BH, 7 Bishopsbourne BH, 8 Barfreston BH, 9 Maydensole BH, 10 Oxney BH and 11 St Margarets BH.*

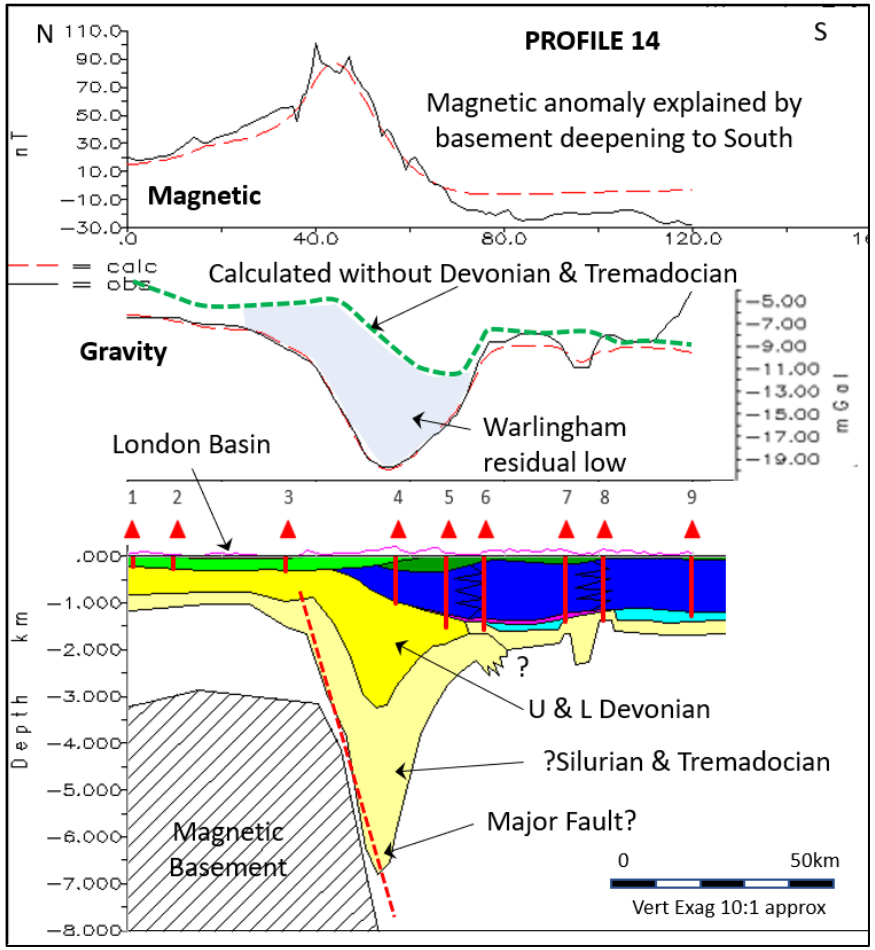
**Profile 13 - Ware BH to St Margaret's BH – North-Southeast orientation – Controlled by 11 wells**

The northern end of the line runs down the southern extension of the Devonian Luton/Cambridge Basin (Allsop, 1985) that appears to lie across the fault zone forming the boundary of the Midlands Platform with the Anglian Basin. The Ware borehole lies on a northwest-southeast trending narrow Silurian ridge and therefore the gravity modelling along the strike of the ridge may be unreliable. To the south of the Ware well, Devonian intervals in the wells shows dips indicative of Variscan deformation in the area. These sequences lie below the Upper Cretaceous and Tertiary cover. A large circular, residual gravity anomaly lies adjacent to the fault zone forming the eastern margin of the Midlands Platform. There are different options for the interpretation of this Canvey Island residual gravity low; a granite (Rabae & Kearey, 1997), a thickened low-density Devonian basin (Allsop, 1985) and (Smart J et al., 1964), or a combination of both. Since the Bobbing and Cliffe Marshes boreholes both lie within the area of the residual low and both proved to be missing Devonian section, our preference is for the granitic block interpretation option. The magnetic data suggest a change in magnetic basement depth with shallower basement north of the Canvey Island Granite (in agreement with Profile 14 below) but the magnetic modelling is considered unreliable as a result of the marked 'dogleg' in the profile. Southeast of the Cliffe Marshes borehole, Silurian and Ordovician sediments, thought to have been deformed during the Acadian Orogeny, are developed. Southeast of the Chilham borehole, a southeasterly thickening wedge of Devonian and Lower Carboniferous underlies the Mesozoic cover. Thick Upper Carboniferous Westphalian-aged Coal Measures of the Kent Coalfield are developed from the Barfreston borehole to the end of the profile.

| Profile 13 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 13 | 1 | Ware BH | 535310 | 213980 | 0 | 220 | Silurian |
| 13 | 2 | Beckton BH | 542800 | 181650 | 33 | 307 | Lower Devonian |
| 13 | 3 | Cliffe Marshes BH | 571850 | 178580 | 62 | 323 | Silurian |
| 13 | 4 | Bobbing BH | 587480 | 165180 | 83 | 348 | Ordovician |
| 13 | 5 | Chilham BH | 608800 | 154550 | 107 | 369 | Silurian |
| 13 | 6 | Lower Hadres BH | 614150 | 152890 | 112 | 460 | Upper Devonian |
| 13 | 7 | Bishopsbourne BH | 619100 | 152900 | 117 | 930 | Lower Carboniferous |
| 13 | 8 | Barfreston BH | 626610 | 150270 | 125 | 955 | U. Carb (U. Coal Measures) |
| 13 | 9 | Maydensole BH | 631680 | 147450 | 131 | 1069 | U. Carb (U. Coal Measures) |
| 13 | 10 | Oxney BH | 635220 | 146950 | 135 | 1095 | U. Carb (U. Coal Measures) |
| 13 | 11 | St Margarets BH | 636650 | 145330 | 137 | 1137 | U. Carb (U. Coal Measures) |

*Table 13 Profile 13 well data*

**Profile 14 - Ware BH to Fairlight-1 – North-South orientation – Controlled by 9 wells**



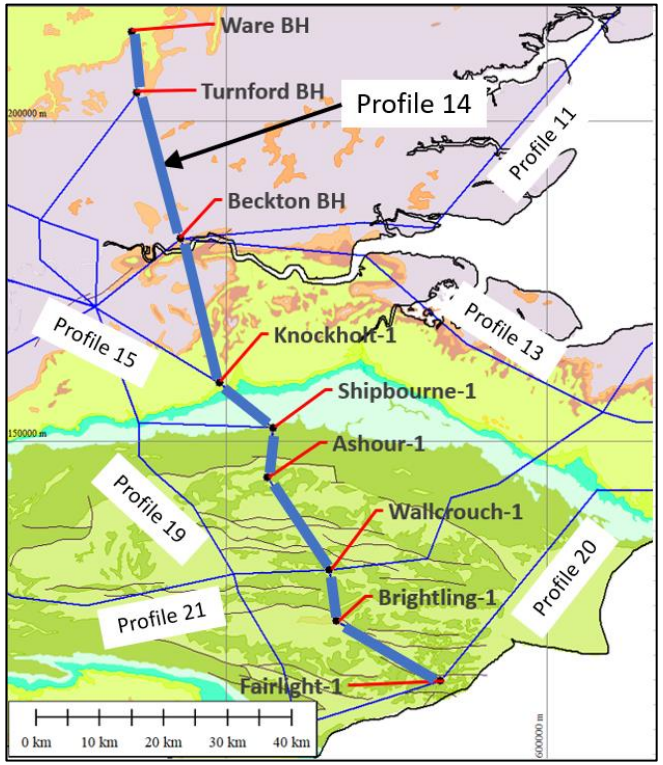




*Figure 17* ***Profile 14*** *Assumed densities are Tertiary 2.2, Upper Cretaceous 2.35, Lower Cretaceous 2.4, Jurassic 2.55/2.62 (central inverted section), Triassic 2.5, Lower Carboniferous 2.75, U & L Devonian 2.62/2.6 (south), Tremadocian 2.67, Magnetic Basement 2.72, 0.015 SI. A background density of 2.72 has been assumed. The well locations are numbered as 1 Ware BH, 2 Turnford BH, 3 Beckton BH, 4 Knockholt-1, 5 Shipbourne-1, 6 Ashour-1, 7 Wallcrouch-1, 8 Brightling-1 and 9 Fairlight-1.*

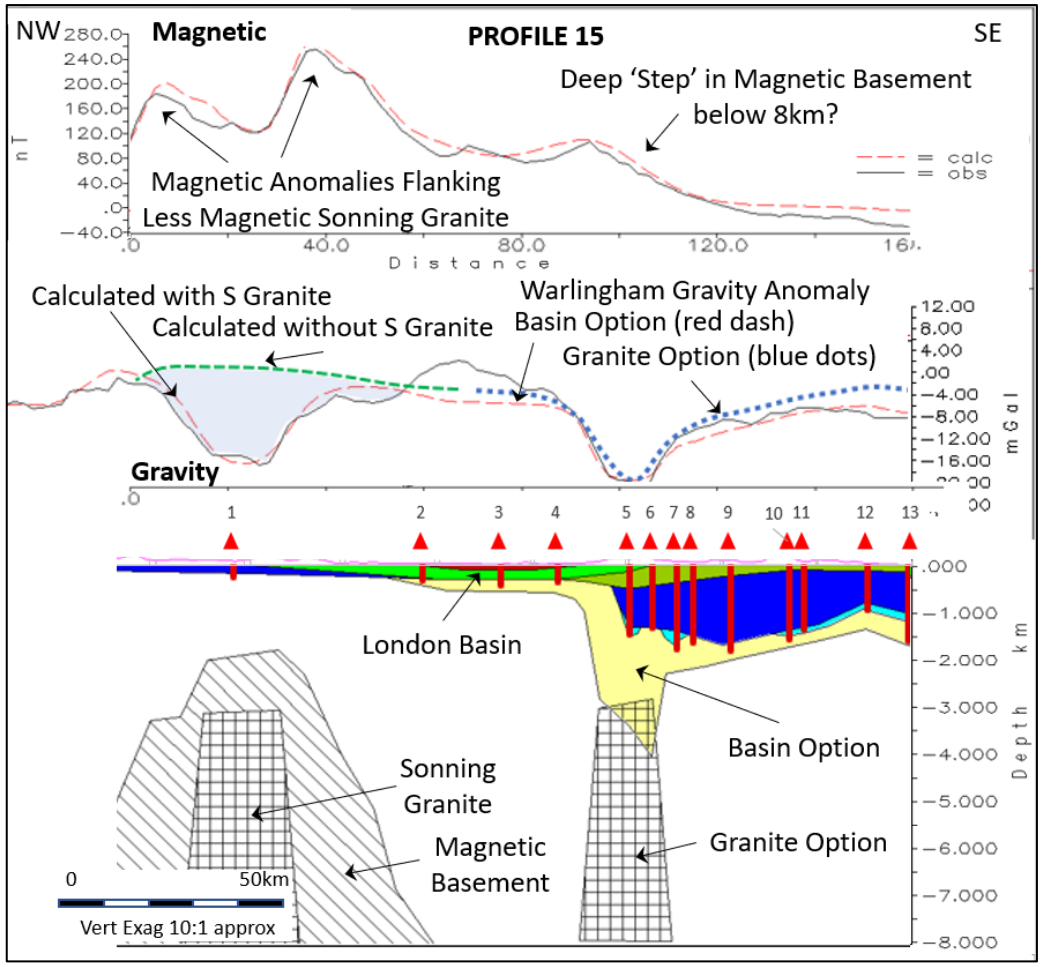
**Profile 14 - Ware BH to Fairlight-1 – North-South orientation – Controlled by 9 wells**

The northern end of the line is located near the western edge of the Anglian Basin. Gravity modelling at the north-western end of the profile is unreliable as the Ware borehole is thought to be located on a narrow, northwest-southeast trending, Silurian ridge, flanked by Devonian section. At the surface, the Upper Cretaceous section outcrops, with Tertiary sediments outcropping as the London Basin is reached. A significant negative residual gravity anomaly (Warlingham Anomaly (Kearey & Rabae, 1996)) presents a problem with interpretation (see Profiles 15, 18 and 19). In this profile, it is explained by a dramatic thickening of the Paleozoic section, possibly comprising thick Devonian and Tremadocian sediments (see the analogous deep basin proven both by drilling and seismic data at approximately 40km along Profile 18). This is partially confirmed by the results of the wells at Turnford, Willesden and Meux Brewery (Tottenham Court Road) where thick Devonian sediments were encountered. The northern margin of the Warlingham Anomaly is associated with an interpreted zone of Variscan deformation that runs to the northeast and crosses the profile between the Ware and Beckton boreholes. High dips in the Devonian, and an older subcrop, are seen in wells to the south of this line with lower dips and younger Devonian subcrop in wells to the north. A major change and southerly deepening of the magnetic basement are coincident with this deformation zone (see Profile 13 above), with the Warlingham Anomaly located immediately to the south. The Knockholt-1 well lies close to the northern edge of the Weald Basin. The profile then crosses the centre of the Weald Basin where a thick inverted Mesozoic section is preserved to the southern end of the profile at Fairlight-1.

| Profile 14 | Well No | Well Name | X | Y | Distance Along Profile | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 14 | 1 | Ware BH | 535310 | 213980 | 0 | 220 | Silurian |
| 14 | 2 | Turnford BH | 535965 | 204416 | 10 | 247 | Upper Devonian |
| 14 | 3 | Beckton BH | 542800 | 181650 | 33 | 307 | Lower Devonian |
| 14 | 4 | Knockholt-1 | 548900 | 159110 | 57 | 999 | Lower Devonian |
| 14 | 5 | Shipbourne-1 | 557290 | 152025 | 68 | 1505 | Silurian |
| 14 | 6 | Ashour-1 | 556400 | 144240 | 76 | 1560 | Lower Carboniferous |
| 14 | 7 | Wallcrouch-1 | 566057 | 129803 | 93 | 1377 | Lower Carboniferous |
| 14 | 8 | Brightling-1 | 567250 | 121820 | 101 | 1353 | Upper Devonian |
| 14 | 9 | Fairlight-1 | 583400 | 112500 | 120 | 1271 | Upper Devonian |

*Table 14 Profile 14 well data*

**Profile 15 – Westham-1 to Chalgrove BH – Northwest-Southeast orientation - Controlled by 13 wells**



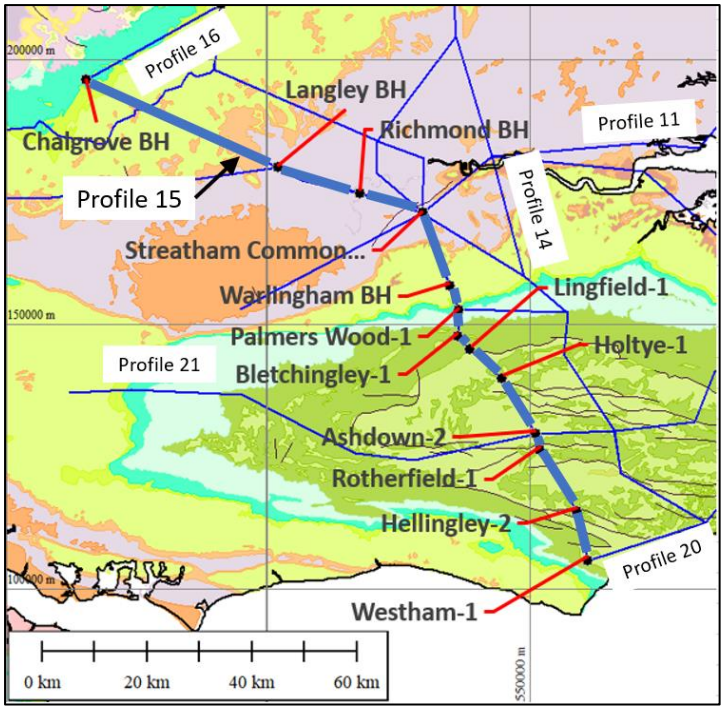




*Figure 18* ***Profile 15*** *Assumed densities are Tertiary 2.25, Upper Cretaceous 2.3, Lower Cretaceous 2.45, Jurassic 2.55 & 2.6 (Inverted Weald), Lower Carboniferous 2.7, Paleozoic Basin Option 2.57, Granite Option 2.62, Sonning Granite 2.6, 0.02 SI, Deep Magnetic Basement 2.72, 0.04 SI. A background density of 2.72 has been assumed. The well locations are numbered as 1-Chalgrove BH, 2-Langley BH, 3-Richmond BH, 4-Streatham Common BH, 5-Warlingham BH, 6-Palmers Wood-1, 7-Bletchingley-1, 8-Lingfield-1, 9-Holtye-1, 10-Ashdown-2, 11-Rotherfield-1, 12-Hellingly-2, and 13-Westham-1.*

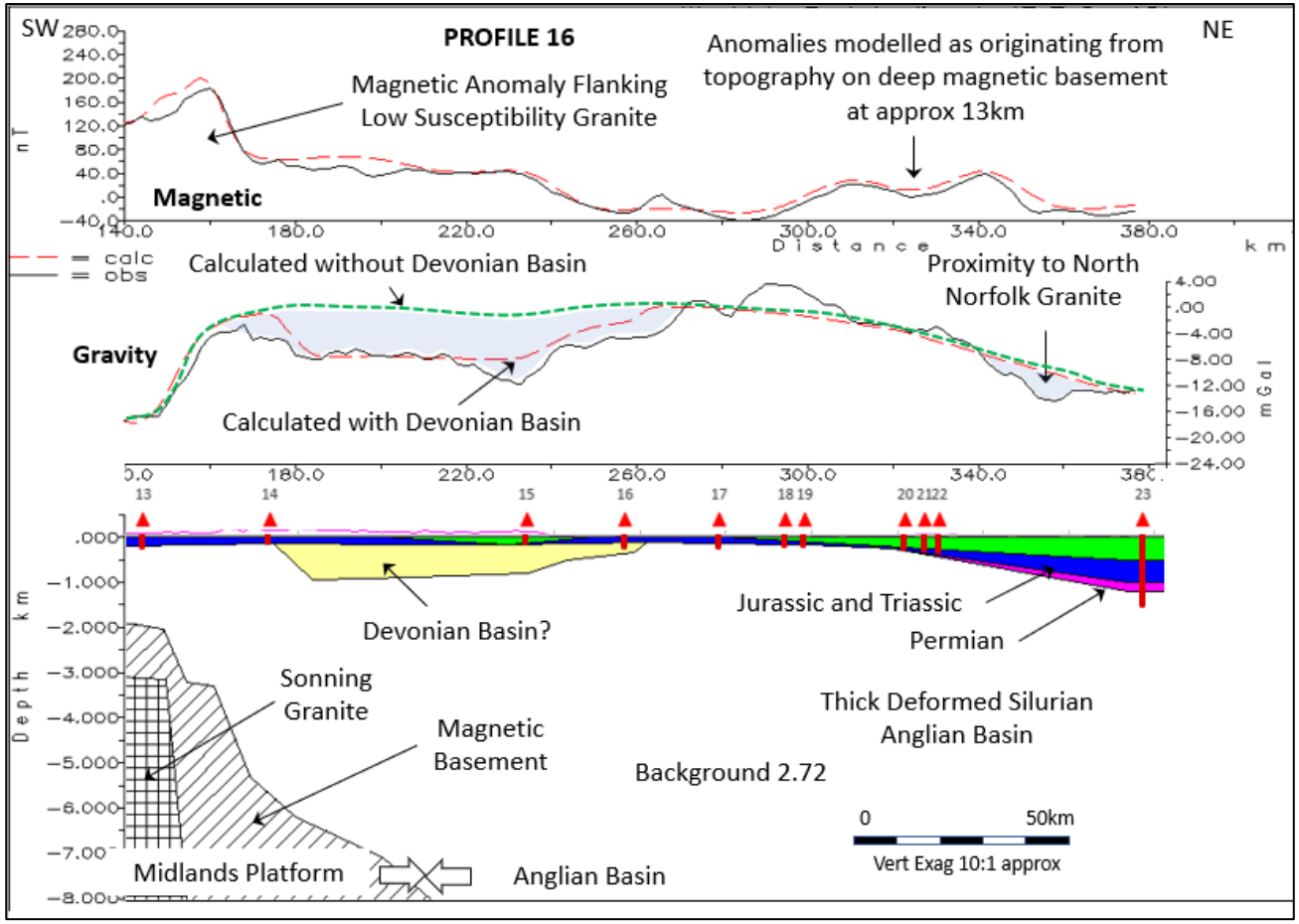
**Profile 15 – Westham-1 to Chalgrove BH – Southeast-Northwest orientation - Controlled by 13 wells**

The profile starts at the Westham-1 well, close to the south coast, and crosses the Weald Basin, where a thick Jurassic section is developed beneath Cretaceous rocks at the surface. The northern edge of the Basin is crossed adjacent to the Bletchingley-1 well, coincident with the southern edge of Upper Cretaceous outcrop. North of the well, there is a significant negative residual gravity anomaly, the Warlingham Anomaly. As mentioned earlier, this anomaly is difficult to interpret, and alternative options exist. In this profile, it is suggested that the low may be due to a thick low-density Paleozoic basin, as shown in the 'Basin Option' (red dashed curve). Alternatively, the observed anomaly is similar in both wavelength and amplitude to the Sonning Granite gravity low and this may suggest a 'Granite Option' (blue dotted curve). A third alternative, Kearey and Rabae (Kearey & Rabae, 1996) propose a major thrust above a wedge of low-density Upper Paleozoic rocks. For further discussion, see Profiles 14, 18 and 19. Further north, Tertiary section outcrops and dips to the north into the London Basin. A positive gravity anomaly on the north side of the Warlingham Anomaly may reflect possible inversion effects of Variscan tectonism on Upper Devonian and older sequences and/or more indurated Lower Paleozoic section associated with a southeasterly extension of the Tamworth-Aylesbury High. North of the Richmond borehole, the Cretaceous and Tertiary strata at the surface dip to the south. A significant negative gravity anomaly to the south of the Chalgrove borehole is thought to be caused by the presence of the Sonning Granite (Rabae & Kearey, 1997). In common with some other granites, flanking magnetic anomalies may be seen, thought to be related to the lower susceptibility granite intruded into more magnetic basement. At the Chalgrove borehole, the profile 'doglegs' to the north-east and continues as Profile 16 below.

| Profile 15 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 15 | 1 | Chalgrove BH | 465650 | 196200 | 19 | 253 | Lower Carboniferous |
| 15 | 2 | Langley BH | 502000 | 179600 | 59 | 326 | Upper Devonian |
| 15 | 3 | Richmond BH | 517640 | 174690 | 75 | 435 | Upper Devonian |
| 15 | 4 | Streatham Common BH | 529560 | 170980 | 87 | 354 | Lower Devonian |
| 15 | 5 | Warlingham BH | 534760 | 157190 | 102 | 1448 | Lower Carboniferous |
| 15 | 6 | Palmers Wood-1 | 536445 | 152623 | 107 | 1319 | Upper Devonian |
| 15 | 7 | Bletchingley-1 | 536225 | 147727 | 112 | 1784 | Lower Carboniferous |
| 15 | 8 | Lingfield-1 | 538664 | 145172 | 116 | 1618 | Middle Jurassic |
| 15 | 9 | Holtye-1 | 544743 | 139773 | 124 | 1790 | Upper Devonian |
| 15 | 10 | Ashdown-2 | 551070 | 129240 | 136 | 1562 | Triassic |
| 15 | 11 | Rotherfield-1 | 551850 | 126249 | 139 | 1362 | Lower Carboniferous |
| 15 | 12 | Hellingly-2 | 558872 | 114656 | 153 | 940 | Lower Carboniferous |
| 15 | 13 | Westham-1 | 560970 | 105350 | 162 | 1589 | Upper Devonian |

*Table 15 Profile 15 well data*

**Profile 16 - Chalgrove BH to Bacton-2– Southwest-Northeast orientation - Controlled by 11 wells**



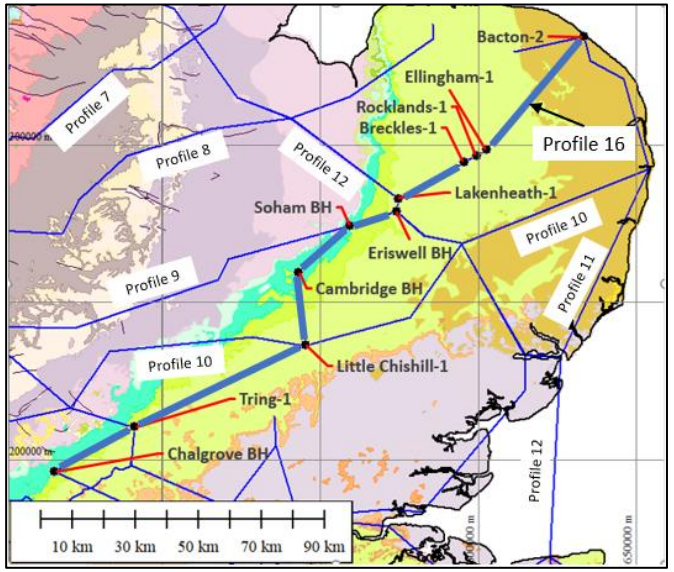




*Figure 19* ***Profile 16*** *Assumed densities are Tertiary 2.25, Upper Cretaceous 2.3, Lower Cretaceous 2.45, Jurassic and Triassic 2.55, Permian 2.55, Devonian 2.5, Sonning Granite 2.6, 0.02 SI, Deep Magnetic Basement 2.72, 0.04 SI, Anglian basin 2.742. A background density of 2.72 has been assumed. The well locations are numbered as 13 Chalgrove BH, 14 Tring-1, 15 Little Chishill-1, 16 Cambridge BH, 17 Soham BH, 18 Eriswell BH, 19 Lakenheath-1, 20 Breckles-1, 21 Rocklands-1, 22 Ellingham-1 and 23 Bacton-2.*

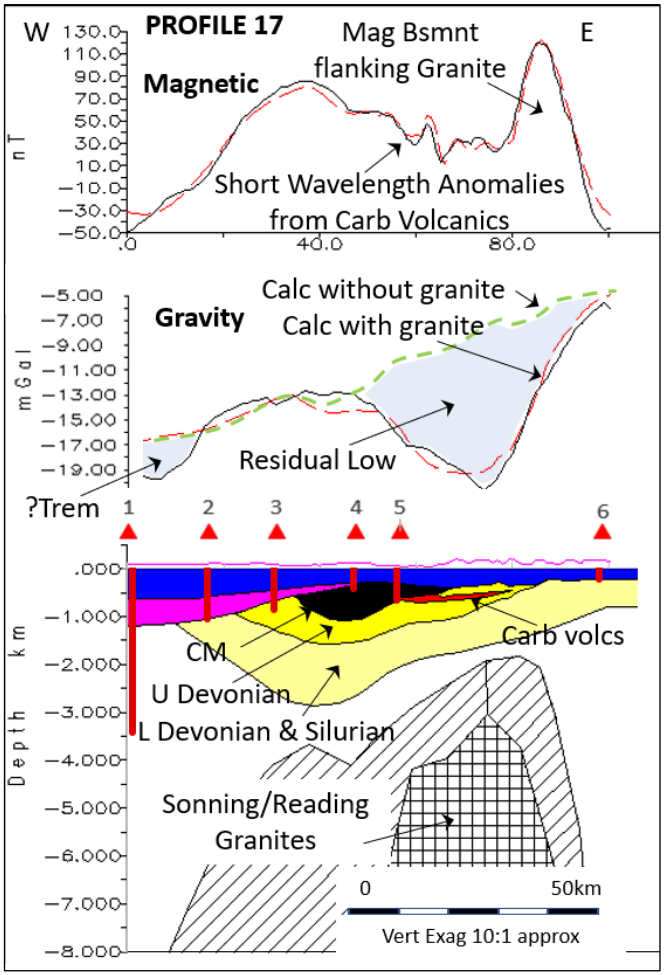
**Profile 16 - Chalgrove BH to Bacton-2 – Southwest-Northeast orientation - Controlled by 11 wells**

This profile commences at the Chalgrove borehole, corresponding to the northwestern end of Profile 15, with Devonian sediments subcropping the Mesozoic (Horton et al., 1995). Northwest of the Chalgrove borehole, the subcrop to the Mesozoic changes from Devonian to Ordovician Tremadocian as the Tamworth-Aylesbury High is crossed. To the north, in the vicinity of the Little Chishill-1 well and Cambridge boreholes, a Devonian basin (the Luton/Cambridge Basin of Allsop, (1985)) is thought to be present, adjacent to the eastern edge of the Midlands Platform. Beyond the Cambridge borehole, deformed Silurian section of the Anglian Basin subcrops the Mesozoic. Magnetic basement is thought to be deep, and the Silurian section is believed to have undergone burial and then uplift during the Acadian deformation event. Beyond the Breckles-1 well, the Mesozoic and Permian section thickens, and the top Paleozoic surface deepens towards the Southern North Sea Permian Basin, with Ordovician sequences subcropping in the Bacton-2 well. A small residual gravity low can be seen near the northeast end of the profile due to proximity to the North Norfolk Granite (Chronston, et al., 1987).

| Profile 16 | Well No | Well Name | X | Y | Distance Along Profile | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 16 | 13 | Chalgrove BH | 465650 | 196200 | 144 | 253 | Lower Carboniferous |
| 16 | 14 | Tring-1 | 491210 | 210360 | 173 | 152 | Sequence 1 (Camb-Trem) |
| 16 | 15 | Little Chishill-1 | 545280 | 236370 | 233 | 154 | U.Devonian |
| 16 | 16 | Cambridge BH | 543140 | 259450 | 256 | 240 | U.Devonian |
| 16 | 17 | Soham BH | 559250 | 274470 | 278 | 237 | Silurian |
| 16 | 18 | Eriswell BH | 574250 | 278860 | 294 | 197 | Silurian |
| 16 | 19 | Lakenheath-1 | 574800 | 283000 | 298 | 209 | Silurian |
| 16 | 20 | Breckles-1 | 595510 | 294690 | 322 | 291 | Silurian |
| 16 | 21 | Rocklands-1 | 599520 | 296700 | 326 | 318 | Silurian |
| 16 | 22 | Ellingham-1 | 602620 | 298470 | 330 | 337 | Silurian |
| 16 | 23 | Bacton-2 | 633386 | 334458 | 377 | 1524 | Ordovician |

*Table 16 Profile 16 well data*

**Profile 17 – Midlands Platform - Cooles Farm-1 to Little Missenden BH – West-East orientation – Controlled by 6 wells**



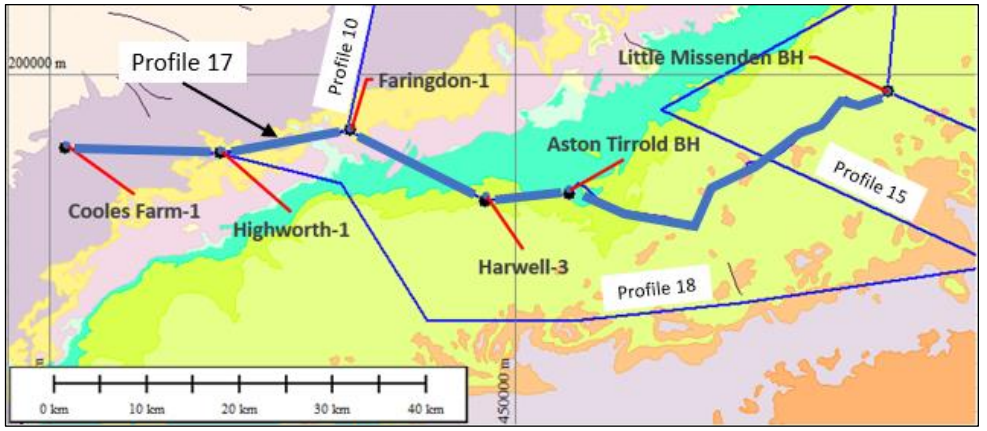




*Figure 20* ***Profile 17*** *Assumed densities are Cretaceous (omitted from profile, thin section), Jurassic 2.4, Permo-Triassic 2.35, Coal Measures 2.55, Carboniferous Volcanics 2.72, 2.7SI 90°, Upper Devonian 2.65, Lower Devonian 2.68, Granite 2.62, Basement Ridge 2.72, 0.027 SI. A background density of 2.72 has been assumed. Wells are numbered as 1 Cooles Farm-1, 2 Highworth-1, 3 Faringdon-1, 4 Harwell-3, 5 Aston Tirrold BH and 6 Little Missenden BH.*

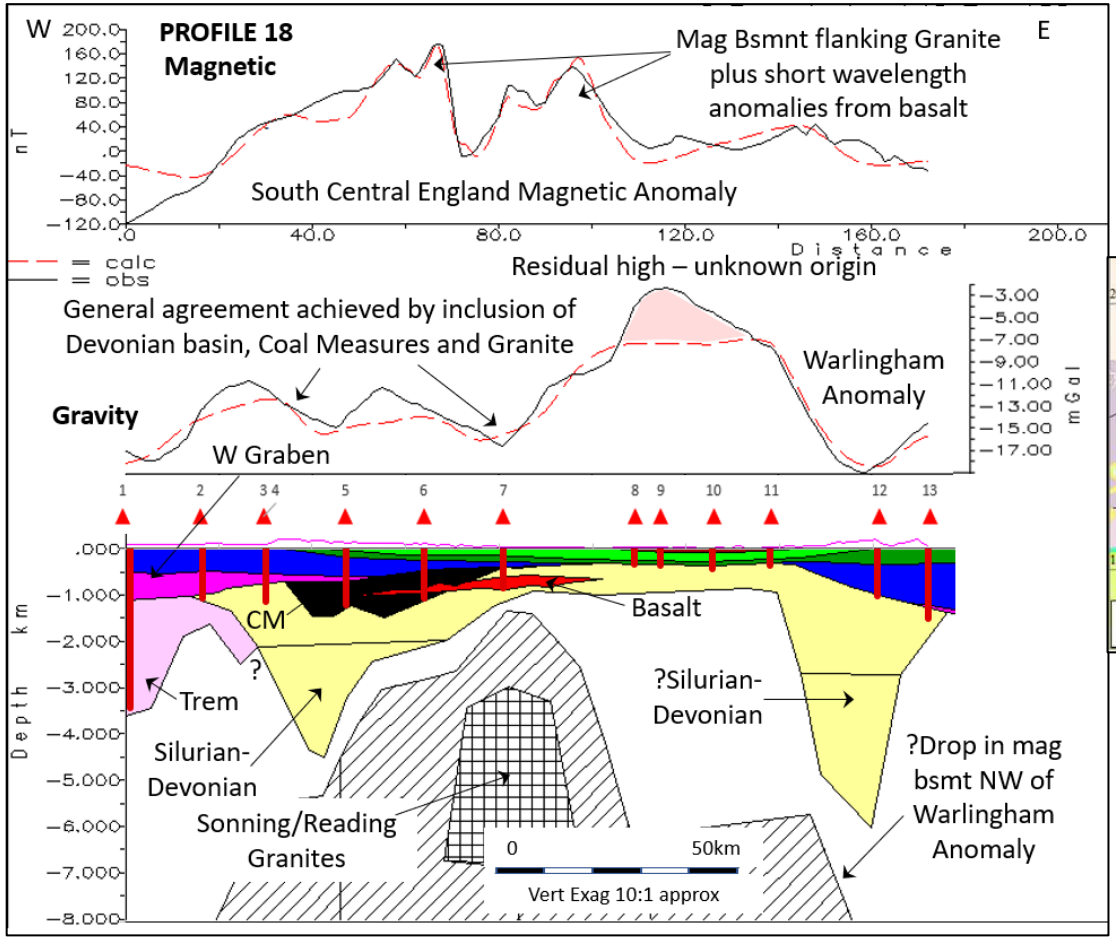
**Profile 17 - Cooles Farm-1 to Little Missenden BH– West-East orientation – Controlled by 6 wells**

The western end of the line begins at Cooles Farm-1 in the southern end of the Worcester Graben where thick Triassic and Jurassic sediments unconformably overly a thick Tremadocian section. Beyond the eastern margin of the graben, a Lower Devonian to Silurian sequence is developed which thickens to the east. The sequence also thickens considerably to the north and south of the profile, as defined by well and seismic data (Butler, 2018), forming a north-south trending basin divided into two sub-basins, one to the north and one to the south of the town of Wantage. We suggest the composite basin be named the Wantage Basin (see Profile 10). This sequence is overlain by a widely developed sequence of Devonian unconformably overlain by the Upper Carboniferous Coal Measures of the Berkshire-Oxfordshire Coalfield. Thin Coal Measures (7m) possibly penetrated in Highworth-1 (missing in Faringdon-1) have been excluded from the model. The Upper and Lower Paleozoic intervals thin and are eroded and pinch out below the Mesozoic as the intervals rise towards the Tamworth-Aylesbury High. The Triassic beds also thin and pinch out on the flanks of the high. At the surface, Cretaceous beds crop out east of the Aston Tirrold borehole (this thin section is not included in the model). The significant residual gravity anomaly, east of the Harwell-3 well, is thought to be due to the presence of the Reading and Sonning Granites. The granite model will be approximate since the profile passes between the centre of the two closely-spaced granite blocks. Shallow Carboniferous volcanics (e.g. a 13m section of volcanics was penetrated in the Aston Tirrold borehole at a depth of approximately 700m) produce short wavelength magnetic anomalies superimposed upon longer wavelength features, thought to originate from magnetic basement at a depth of at least 2km and flanking the non-magnetic granitic core believed to be Precambrian. The residual gravity low on the southwest end of the profile probably originates from a thick Tremadocian section, seen in the Cooles Farm-1 well, and not included in the model profile but included in Profile 18 below.

| Profile 17 | Well No | Well Name | X | Y | Distance Along Profile | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 17 | 1 | Cooles Farm-1 | 401641 | 192135 | 0 | 3418 | Sequence 1 (Camb-Trem) |
| 17 | 2 | Highworth-1 | 418314 | 191528 | 17 | 1057 | Silurian |
| 17 | 3 | Faringdon-1 | 432240 | 193980 | 31 | 864 | Lower Devonian |
| 17 | 4 | Harwell-3 | 446801 | 186441 | 47 | 428 | U. Carb (U. Coal Measures) |
| 17 | 5 | Aston Tirrold BH | 455790 | 187220 | 56 | 689 | Upper Devonian |
| 17 | 6 | Little Missenden BH | 490090 | 198180 | 98 | 245 | Silurian |

*Table 17 Profile 17 well data*

**Profile 18 - Cooles Farm-1 to Shipbourne-1 – West-East orientation - Controlled by 13 wells.**



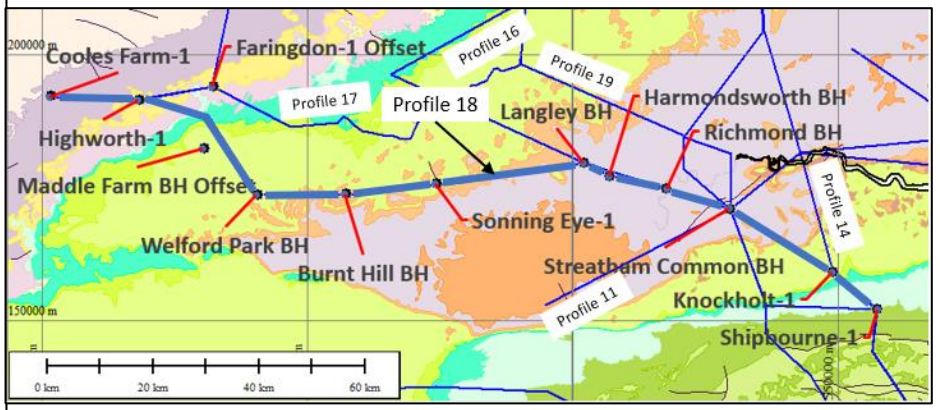




*Figure 21* ***Profile 18*** *Assumed densities are Tertiary 2.3, Upper Cretaceous 2.35, Lower Cretaceous 2.35, Jurassic 2.5, Permo-Triassic 2.35 (Worcester Graben) and 2.5 (Inverted Weald), Coal Measures 2.55, Carboniferous Volcanics 2.72, rem mag 3.5SI 90°, Devonian 2.65 (upper parts), 2.7 (lower part) and 2.67 (lower part Warlingham), Tremadocian 2.67, Magnetic Basement 2.72, rem mag 1.6SI 90° (west), 1.3SI 90° (central) and 1.0SI 90° (east) . A background density of 2.72 has been assumed. Wells are numbered as 1 Cooles Farm-1, 2 Highworth-1, 3 Faringdon-1 (offset), 4 Maddle Farm BH (offset), 5 Welford Park BH, 6 Burnt Hill BH, 7 Sonning Eye-1, 8 Langley BH, 9 Harmondsworth BH, 10 Richmond BH, 11 Streatham Common BH, 12 Knockholt-1 and 13 Shipbourne-1.*

**Profile 18 - Cooles Farm-1 to Shipbourne-1 – West-East orientation - Controlled by 13 wells**

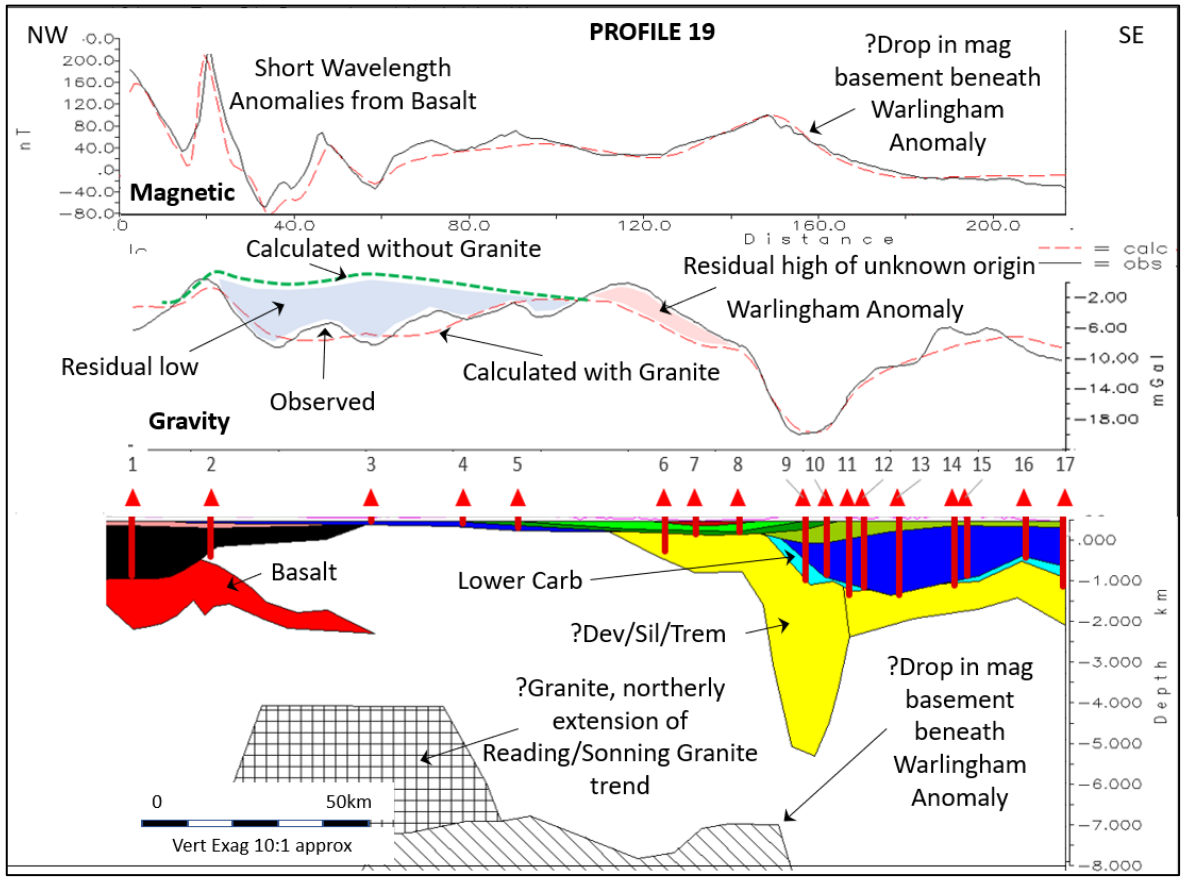
The western end of the line begins at Cooles Farm-1 in the Worcester Graben where thick Triassic and Jurassic sections unconformably overly a thick Ordovician Tremadocian section. Beyond the eastern margin of the graben, a Lower Devonian to Silurian sequence thickens to the east. It is overlain by Upper Devonian sediments, with the Upper Carboniferous Coal Measures of the Berkshire-Oxfordshire Coalfield developed along the axis of the syncline. The remarkably thick Silurian-Devonian section (Wantage Basin, see Profile 17) is defined by seismic and well data (Butler, 2018). Jurassic sequences onlap and overstep the Triassic to the east before pinching out beyond the Sonning Eye well. The profile crosses the broad South-Central England Magnetic Anomaly with a core of lower magnetic values associated with the lower susceptibility Reading and Sonning Granites. A large negative residual gravity anomaly, east of the Burnt Hill borehole, is thought to be associated with these granites. Shallow volcanics of Carboniferous age are seen in the Burnt Hill and Sonning Eye wells. Short-wavelength magnetic anomalies are associated with these volcanics, with longer-wavelength features related to a deeper magnetic basement flanking the granite intrusion. The source depth to the core of these longer wavelength magnetic features is unclear. Busby et al. (2006) suggest a depth to the top of between 2 to 3km whereas Kearey (1991) and Beamish et al. (2016) prefer the main component of the anomaly to originate from a much deeper source within the middle crust. Whatever depth the source may be, it is a large and significant anomaly and is offset to the southwest from the Tamworth-Aylesbury Ridge. Above and beyond the anomaly, the Upper Cretaceous sequence with overlying Tertiary dips to the east into the London Basin. Past the Langley BH, the profile runs across the positive residual gravity anomaly (also seen on Profiles 14, 15 and 19) that extends as far as the northwest side of the Warlingham gravity low Anomaly. The origin for this residual high is uncertain but it may be related to a Variscan-aged deformation belt developed north of the Warlingham Anomaly. Alternatively, the positive anomaly lies on trend with the southeastern end of the Tamworth-Aylesbury High and it may represent a buried extension of this Pre-Triassic topographic ridge. The postulated Variscan-aged deformation belt is associated with a major change in the magnetic character and suggests a rapid southerly deepening of magnetic basement. The negative gravity anomaly associated with the Warlingham area is difficult to interpret (see Profiles 14, 15 and 19) but may be due to thick Lower Paleozoic and Devonian sequences, (for an alternative explanation see Profile 15), analogous to the deep basin beneath the Berkshire-Oxfordshire Coalfield, and developed below a southerly thickening Jurassic and Cretaceous sedimentary wedge.

| Profile 18 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 18 | 1 | Cooles Farm-1 | 401641 | 192135 | 0 | 3418 | Sequence 1 (Camb-Trem) |
| 18 | 2 | Highworth-1 | 418314 | 191528 | 17 | 1057 | Silurian |
| 18 | 3 | Faringdon-1 Offset | 432240 | 193980 | 30 | 864 | Lower Devonian |
| 18 | 4 | Maddle Farm BH Offset | 430530 | 182330 | 30 | 1130 | Upper Devonian |
| 18 | 5 | Welford Park BH | 440660 | 173640 | 47 | 1190 | U. Carb (U. Coal Measures) |
| 18 | 6 | Burnt Hill BH | 457200 | 173800 | 64 | 1053 | U. Carb (U. Coal Measures) |
| 18 | 7 | Sonning Eye-1 | 474266 | 175650 | 81 | 831 | Upper Devonian |
| 18 | 8 | Langley BH | 502000 | 179600 | 109 | 326 | Upper Devonian |
| 18 | 9 | Harmondsworth BH | 506830 | 177130 | 115 | 342 | Upper Devonian |
| 18 | 10 | Richmond BH | 517640 | 174690 | 126 | 435 | Upper Devonian |
| 18 | 11 | Streatham Common BH | 529560 | 170980 | 138 | 354 | Lower Devonian |
| 18 | 12 | Knockholt-1 | 548900 | 159110 | 161 | 999 | Lower Devonian |
| 18 | 13 | Shipbourne-1 | 557290 | 152025 | 172 | 1505 | Silurian |

*Table 18 Profile 18 well data*

## Southern England

**Profile 19 - Weald Basin to Midlands Platform, Westham-1 to Moreton Morell BH – Northwest-Southeast orientation – Controlled by 17 wells**



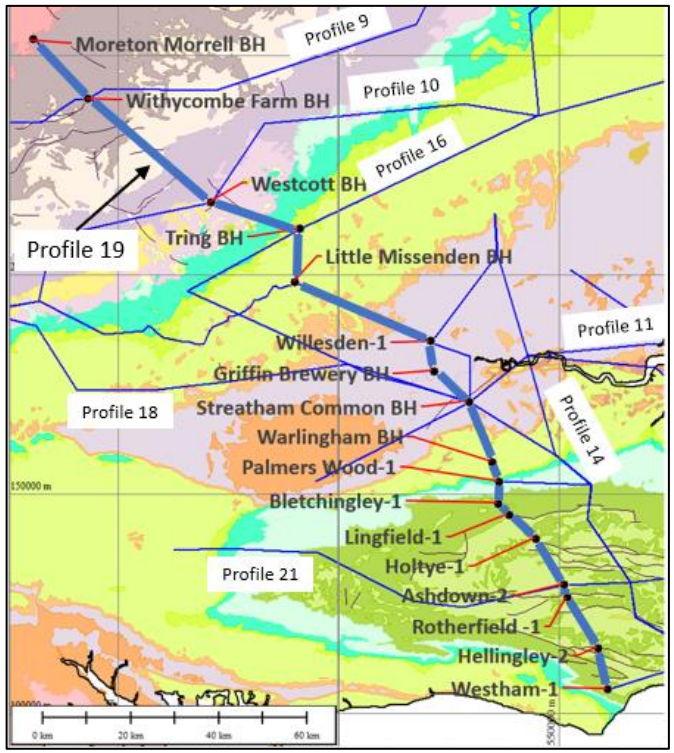




*Figure 22* ***Profile 19*** *Assumed densities are Tertiary 2.2, Upper Cretaceous 2.35, Lower Cretaceous 2.4/2.45 (Inverted Weald), Jurassic 2.4/2.62 (Inverted Weald), Permo-Triassic 2.5, Coal Measures 2.55, Basalt 2.85, rem mag 4.5SI 90°, Devonian 2.62, Granite 2.65, Magnetic Basement 2.72, 0.03SI. A background density of 2.72 has been assumed. Wells are numbered as 1 Moreton Morrell BH, 2 Withycombe farm BH, 3 Westcott BH, 4 Tring BH, 5 Little Missenden BH, 6 Willesden-1, 7 Griffin Brewery BH, 8 Streatham Common BH, 9 Warlingham BH, 10 Palmers Wood-1, 11 Bletchingley-1, 12 Lingfield-1, 13 Holtye-1, 14 Ashdown-2, 15 Rotherfield-1, 16 Hellingly-2 and 17 Westham-1.*

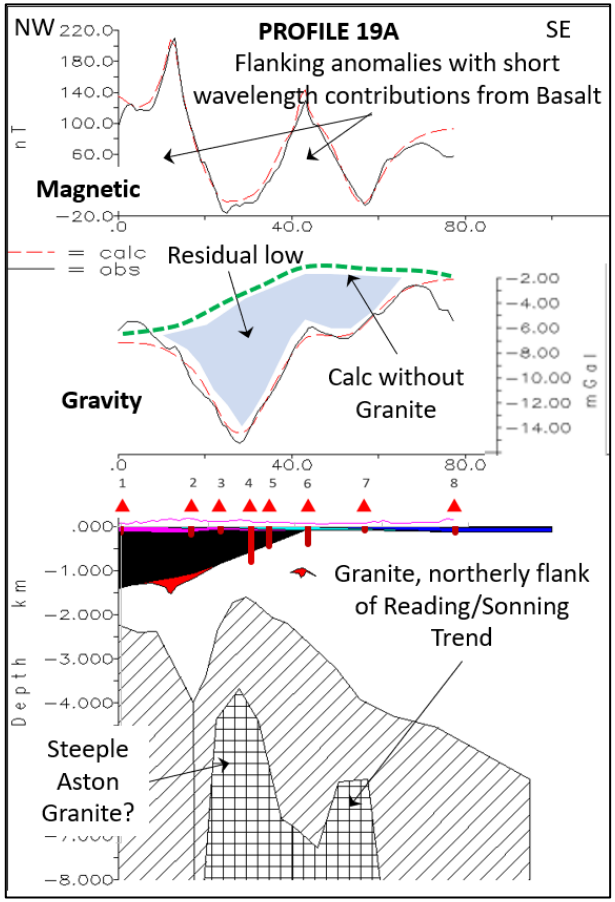
**Profile 19 - Weald Basin to Midlands Platform, Westham-1 to Moreton Morell BH – Northwest-Southeast – Controlled by 17 wells**

The profile crosses the Weald Basin before reaching the northern bounding fault, near Bletchingley-1, where the low gravity values of the Warlingham Anomaly are seen. As discussed earlier, the source of this anomaly is unknown but is thought to be due to the presence of a thick Paleozoic sedimentary sequence (see Profiles 14, 15 and 18 for further discussion). The northern Weald Basin bounding fault is traditionally thought to be the southern edge of the Midlands Platform. However, a major change in the character of the magnetics and a significant shallowing of the magnetic basement occurs along the northern edge of the Warlingham Anomaly suggesting that the limit lies further north. Well data show a Variscan deformation zone to also correspond with the northern edge of the Warlingham Anomaly and this edge may represent a significant tectonic lineament. At the surface, this margin lies close to the southern extent of the Tertiary London Basin. North of the London Basin, the outcrop of the Cretaceous rocks lies just to the south of the Tring borehole. The Jurassic outcrop is replaced by the Triassic outcrop north of the Withycombe Farm borehole. The residual gravity anomaly in the area between the Little Missenden and Withycombe Farm boreholes is thought to be due to the presence of an uplifted sequence of Ordovician Tremadocian rocks, as proved by the work of Merriman R et al, 1993. An anomaly north of the Withycombe Farm borehole seems to be associated with an extension of the Berkshire-Oxfordshire Coalfield. Short wavelength magnetic anomalies are probably associated with shallow Precambrian basalts, as encountered at approximately 470m in the Withycombe Farm borehole. The profile includes Triassic section as seen in the Moreton Morrell and Withycombe Farm boreholes. Further to the southeast, the Triassic section is thought to be thin or absent and has been omitted despite the isolated occurrence of thin Triassic sediments in the Ashdown-2 well.

| Profile 19 | Well No | Well Name | X | Y | Distance Along Profile | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 19 | 1 | Moreton Morrell BH | 430776 | 253643 | 0 | 1361 | Sequence 1 (Camb-Trem) |
| 19 | 2 | Withycombe Farm BH | 443190 | 240170 | 18 | 921 | Precambrian |
| 19 | 3 | Westcott BH | 470960 | 216490 | 55 | 96 | Sequence 1 (Camb-Trem) |
| 19 | 4 | Tring BH | 491210 | 210360 | 76 | 152 | Sequence 1 (Camb-Trem) |
| 19 | 5 | Little Missenden BH | 490090 | 198180 | 89 | 245 | Silurian |
| 19 | 6 | Willesden-1 | 520860 | 184770 | 122 | 785 | Upper Devonian |
| 19 | 7 | Griffin Brewery BH | 521610 | 177920 | 129 | 389 | Upper Devonian |
| 19 | 8 | Streatham Common BH | 529560 | 170980 | 139 | 354 | Lower Devonian |
| 19 | 9 | Warlingham BH | 534760 | 157190 | 154 | 1448 | Lower Carboniferous |
| 19 | 10 | Palmers Wood-1 | 536445 | 152623 | 159 | 1319 | Upper Devonian |
| 19 | 11 | Bletchingley-1 | 536225 | 147727 | 164 | 1784 | Lower Carboniferous |
| 19 | 12 | Lingfield-1 | 538664 | 145172 | 168 | 1618 | Middle Jurassic |
| 19 | 13 | Holtye-1 | 544743 | 139773 | 176 | 1790 | Upper Devonian |
| 19 | 14 | Ashdown-2 | 551070 | 129240 | 188 | 1562 | Triassic |
| 19 | 15 | Rotherfield -1 | 551850 | 126249 | 191 | 1362 | Lower Carboniferous |
| 19 | 16 | Hellingly-2 | 558872 | 114656 | 205 | 940 | Lower Carboniferous |
| 19 | 17 | Westham-1 | 560970 | 105350 | 214 | 1589 | Upper Devonian |

*Table 19 Profile 19 well data*

**Profile 19A - Midlands Platform, Armscote Manor BH to Tring BH – Northwest-Southeast orientation – Controlled by 8 wells**



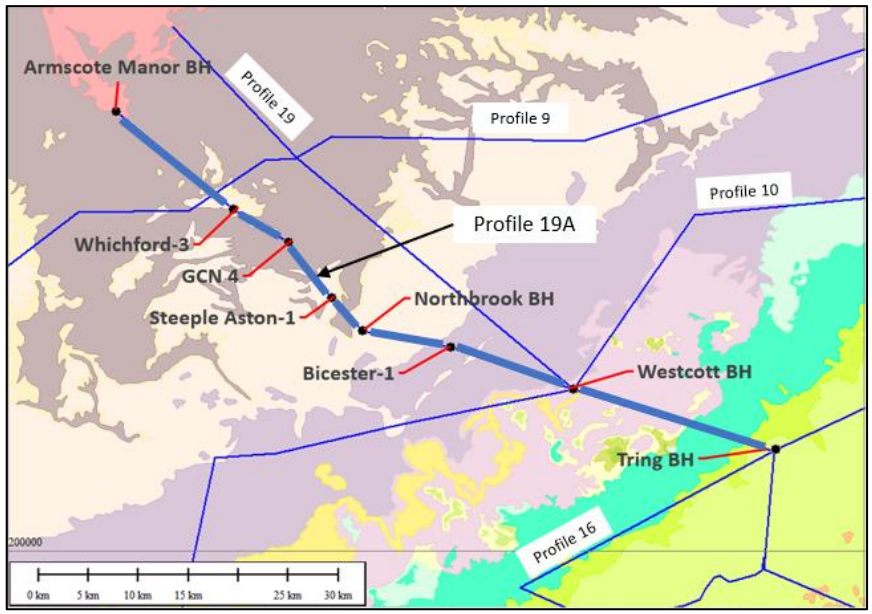




*Figure 23* ***Profile 19A*** *Assumed densities are Lower Cretaceous 2.3, Upper and Middle Jurassic 2.3, Lower Jurassic 2.4, Permo-Triassic 2.4, Coal Measures 2.62, Basalt 2.72 0.08 (NW) & 0.04 (SE), Steeple Aston Granite 2.62, Reading Sonning Trend Granites 2.63, Magnetic Basement 2.72, 0.035SI. A background density of 2.72 has been assumed. Wells are numbered as 1 Armscote Manor BH, 2 Whichford-3, 3 GCN-4, 4 Steeple Aston-1, 5 Northbrook BH, 6 Bicester-1, 7 Westcott BH and 8 Tring BH.*

**Profile 19A - Midlands Platform, Armscote Manor BH to Tring-BH – Northwest-Southeast orientation – Controlled by 8 wells**

Profile 19A is a short profile constructed to provide an alternative, northwesterly extension to the longer Profile 19. The well starts at the Armscote Manor borehole where Lower Jurassic rocks crop out at the surface. To the southeast along the profile, progressively younger Jurassic rocks outcrop until, to the southeast of the Westcott 2 borehole, these sequences are unconformably overlain by Upper Cretaceous rocks which then form the outcrop. The profile passes through the Steeple Aston well where a gravity low has previously been tentatively suggested (J D Cornwell in Horton, et al., 1987) to represent an underlying granite body. The constructed profile shows a significant negative residual gravity anomaly with a value of up to 12mGal. The maximum anomaly is focused on the Steeple Aston-1 well but this merges with an adjacent low located slightly to the southeast. The presence of a small granite mass, here called the Steeple Aston Granite, adjacent to the northerly flank of the Sonning and Reading Granites, is included in the model to explain the residual anomalies. The proposed Steeple Aston Granite lies beneath the eastern edge of the Oxfordshire Coal Field and also immediately to the northeast of thick Devonian section (Butler, 2018), named here as the Wantage Basin. As a result of the interfering anomalies, the model should be regarded as preliminary. The magnetic profile shows two positive magnetic anomalies located in flanking positions to the proposed Steeple Aston Granite, suggesting that the non-magnetic granite mass may be intruded into a slightly magnetic basement. Shorter wavelength components within the magnetic profile may be associated with basalt proven in the nearby Withycombe Farm well (see Profile 19).

| Profile 19A | Well No | Well Name | X | Y | Distance Along Profile | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 19A | 1 | Armscote Manor BH | 424470 | 244790 | 0 | 128 | Triassic Ss |
| 19A | 2 | Whichford-3 | 437037 | 234970 | 16 | 183 | U. Carb (U. Coal Measures) |
| 19A | 3 | GCN 4 | 442600 | 231590 | 23 | 105 | U. Carb (U. Coal Measures) |
| 19A | 4 | Steeple Aston-1 | 446870 | 225860 | 30 | 887 | Upper Devonian |
| 19A | 5 | Northbrook BH | 449940 | 222460 | 34 | 485 | Upper Devonian |
| 19A | 6 | Bicester-1 | 458783 | 220812 | 43 | 428 | Silurian |
| 19A | 7 | Westcott BH | 470960 | 216490 | 56 | 96 | Sequence 1 (Camb-Trem) |
| 19A | 8 | Tring BH | 491210 | 210360 | 77 | 152 | Sequence 1 (Camb-Trem) |

*Table 20 Profile 19A well data*

**Profile 20 – Weald basin to Kent Coalfield - Hellingley-2 to St Margarets BH – Southwest-Northeast orientation – Controlled by 10 wells**

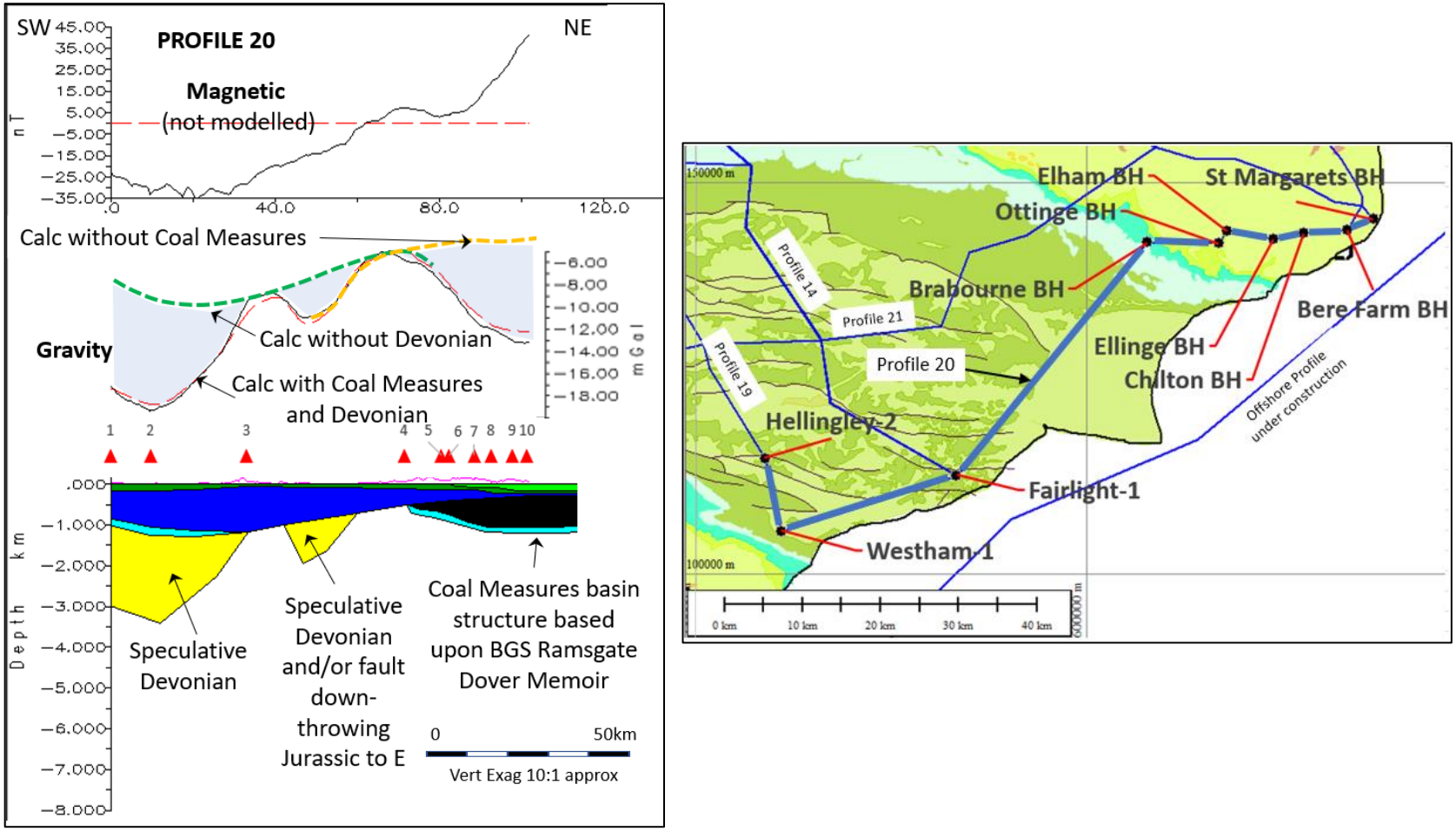



*Figure 24* ***Profile 20*** *Assumed densities are U Cretaceous 2.35, L Cretaceous 2.4, Jurassic 2.525, Coal Measures 2.45, L Carboniferous 2.7 and Devonian 2.6. A background density of 2.72 has been assumed. Wells are numbered as 1 Hellingley-2, 2 Westham-1, 3 Fairlight-1, 4 Brabourne BH, 5 Ottinge BH, 6 Elham BH, 7 Ellinge BH, 8 Chilton BH, 9 Bere Farm BH and 10 St Margarets BH.*

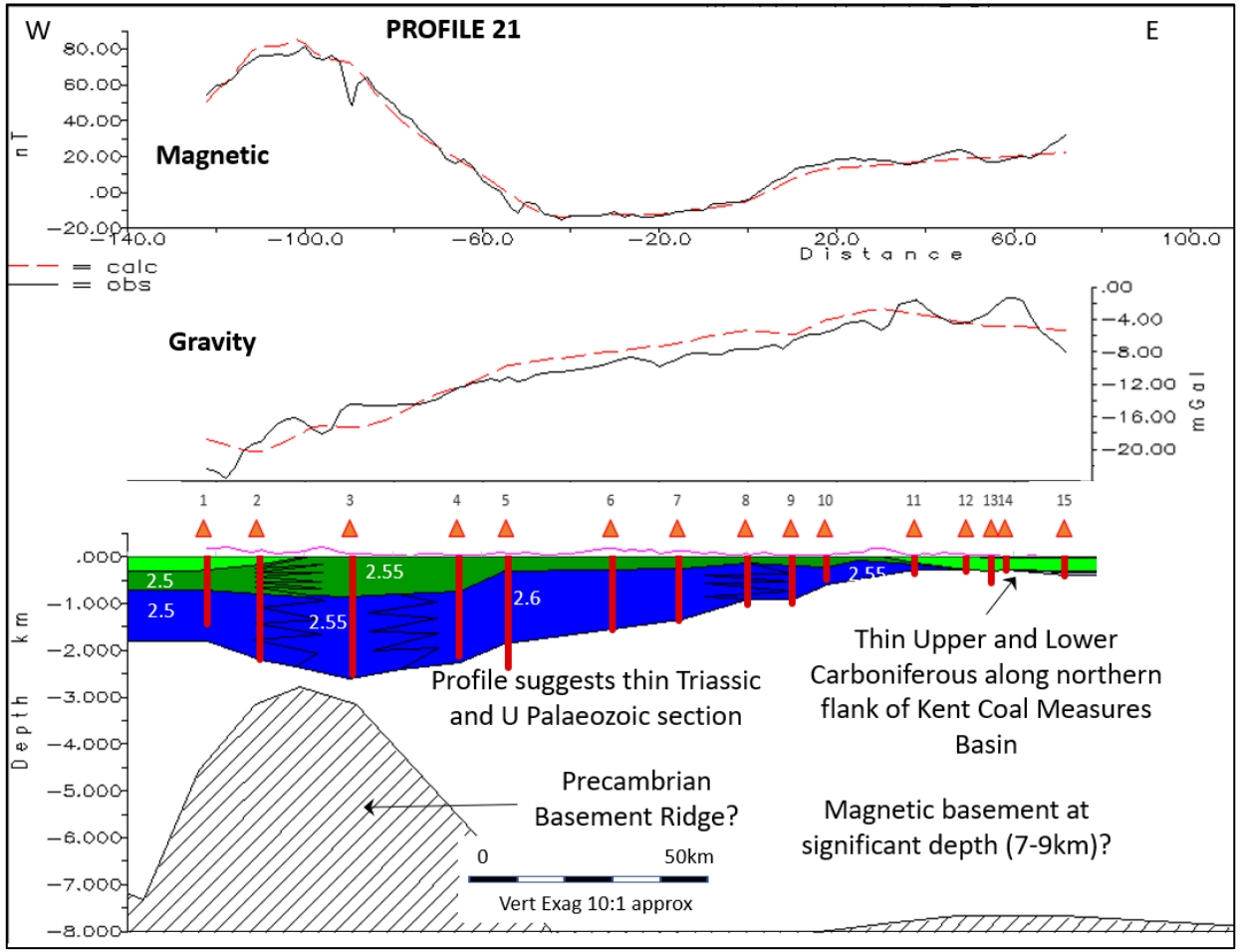
**Profile 20 – Hellingley-2 to St Margarets BH – Southwest-Northeast orientation – Controlled by 10 wells**

This profile crosses the inverted Weald Basin with a thick Jurassic section below the Cretaceous outcrop. To the south and west, a significant residual anomaly, in excess of 10mGal, suggests the presence of thick pre-Carboniferous low-density sediments, of possible Devonian age. This may reflect an eastern extension of the Portsdown-Paris Plage Ridge. Current gravity modelling in southern England suggests that the possible thick Devonian section, located on the southwestern end of Profile 20, may extend westwards for almost 200km to beyond Salisbury. East of the Weald Basin, seismic data demonstrate the presence of a thick, relatively undeformed, Upper Paleozoic section bounded by a major fault zone located just to the west of the Brabourne borehole. This margin is coincident with the outcrop of the Upper Cretaceous and the progressive eastward thinning of the Mesozoic section. The Kent Coalfield is located within this Upper Paleozoic Basin. Unfortunately, no well density data are currently available for the Coal Measures section, but the model suggests that the Coalfield produces an anomaly of approximately -8mGal.

| Profile 20 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 20 | 1 | Hellingley-2 | 558872 | 114656 | 0 | 940 | Lower Carboniferous |
| 20 | 2 | Westham-1 | 560970 | 105350 | 10 | 1589 | Upper Devonian |
| 20 | 3 | Fairlight-1 | 583400 | 112500 | 33 | 1271 | Upper Devonian |
| 20 | 4 | Brabourne BH | 607760 | 142310 | 72 | 545 | Silurian |
| 20 | 5 | Ottinge BH | 616950 | 142190 | 81 | 164 | Upper Jurassic |
| 20 | 6 | Elham BH | 618000 | 143800 | 83 | 631 | Lower Carboniferous |
| 20 | 7 | Ellinge BH | 623900 | 142700 | 89 | 408 | U. Carb (U. Coal Measures) |
| 20 | 8 | Chilton BH | 627790 | 143460 | 93 | 976 | U. Carb (U. Coal Measures) |
| 20 | 9 | Bere Farm BH | 633360 | 143840 | 98 | 795 | U. Carb (U. Coal Measures) |
| 20 | 10 | St Margarets BH | 636650 | 145330 | 102 | 1137 | U. Carb (U. Coal Measures) |

*Table 21 Profile 20 well data*

**Profile 21 - Old Alresford-1 to Ebbsfleet BH – West-East orientation – Controlled by 15 wells**



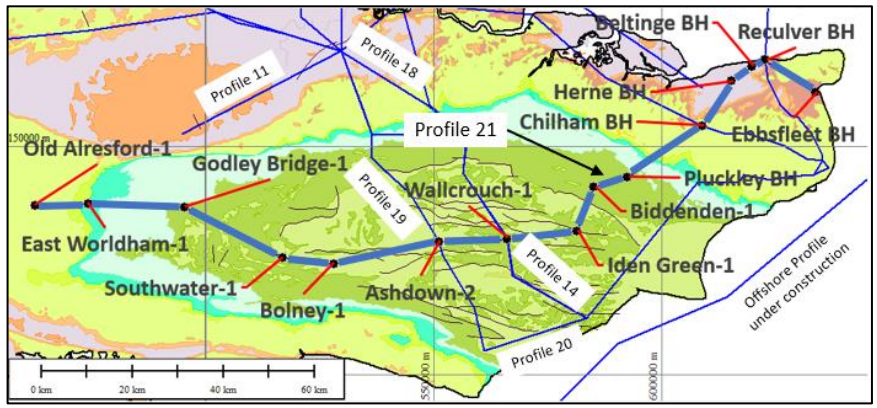




*Figure 25* ***Profile 21*** *Assumed densities are Tertiary 2.35, U Cretaceous 2.35, L Cretaceous 2.5/2.55 (as shown above), Jurassic 2.5/2.55/2.6 (as shown), Coal Measures 2.55, L Carboniferous 2.7, Basement Ridge 2.72, 0.025SI. A background density of 2.72 has been assumed. Wells are numbered as 1 Old Alresford-1, 2 East Worldham-1, 3 Godley Bridge-1, 4 Southwater-1, 5 Bolney-1, 6 Ashdown-2, 7 Wallcrouch-1, 8 Iden Green-1, 9 Biddenden-1, 10 Pluckley BH, 11 Chilham BH, 12 Herne BH, 13 Beltinge BH, 14 Reculver BH and 15 Ebbsfleet BH.*

**Profile 21 - Old Alresford-1 to Ebbsfleet BH – West-East orientation – Controlled by 15 wells**

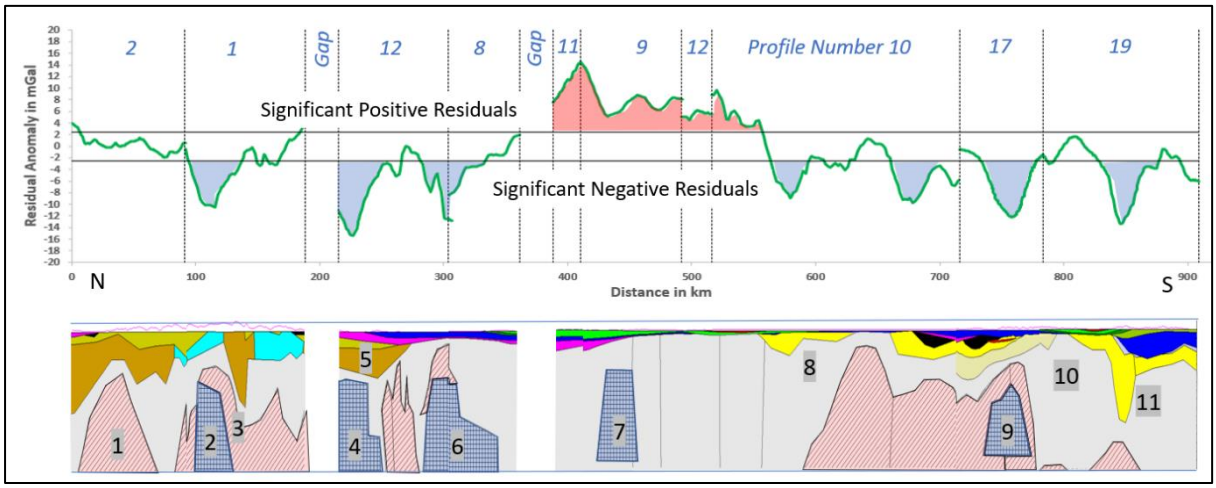
This profile runs eastwards along the axis of the inverted Weald Basin, with Cretaceous rocks at the surface overlying a thick Jurassic section. Well density data suggest that inversion movements have resulted in laterally varying density of the Jurassic and Lower Cretaceous section, with higher densities indicative of greater inversion. The inversion, which is greatest to the east, runs along the axis of the basin (Butler & Pullan, 1990). The magnetic data appear relatively featureless except for a long wavelength, north-south trending magnetic ridge in the vicinity of the East Worldham-1 and Godley Bridge-1 wells. Since the East Worldham-1 well encountered Ordovician Tremadocian section (Molyneux, 2010), it is thought that the source of the magnetic anomaly may lie within the Precambrian, as tentatively modelled here. The gravity model, down to Base Jurassic level, shows no significant residual anomalies, suggesting that the basin is underlain by a relatively thin Triassic and Upper Paleozoic sequence which in turn overlies the Lower Paleozoic, as proved in East Worldham-1 S Molyneux (personal comm). To the east, across the basin-bounding fault to the east of Iden Green-1, the Mesozoic section thins. A major geological boundary, just to the west of the Chilham borehole, marks the margin of the Upper Paleozoic basin within which the Kent Coalfield is located. This boundary does not appear to be associated with a significant change in gravity values on this profile. This margin is coincident with the outcrop of the Upper Cretaceous and the eastward thinning of the Mesozoic section. The profile passes along the northern flank of the Kent Coal Field with a thick Coal Measures sequence occurring to the south together with an associated gravity low (see Profile 20).

| Profile 21 | Well No | Well Name | X | Y | Distance Along Profile (km) | TD TVDSS (m) | TD Formation |
|---|---|---|---|---|---|---|---|
| 21 | 1 | Old Alresford-1 | 462449 | 137078 | -122 | 1458 | Lower Jurassic |
| 21 | 2 | East Worldham-1 | 474062 | 137569 | -110 | 2213 | Sequence 1 (Camb-Trem) |
| 21 | 3 | Godley Bridge-1 | 495232 | 136640 | -89 | 2511 | Triassic |
| 21 | 4 | Southwater-1 | 516736 | 125587 | -65 | 2127 | Triassic |
| 21 | 5 | Bolney-1 | 528011 | 124269 | -54 | 2369 | Upper Devonian |
| 21 | 6 | Ashdown-2 | 551070 | 129240 | -30 | 1562 | Triassic |
| 21 | 7 | Wallcrouch-1 | 566057 | 129803 | -15 | 1377 | Lower Carboniferous |
| 21 | 8 | Iden Green-1 | 581352 | 131568 | 0 | 1028 | Lower Carboniferous |
| 21 | 9 | Biddenden-1 | 585078 | 141105 | 10 | 1011 | Silurian |
| 21 | 10 | Pluckley BH | 592400 | 143270 | 18 | 486 | Upper Jurassic |
| 21 | 11 | Chilham BH | 608800 | 154550 | 38 | 369 | Silurian |
| 21 | 12 | Herne BH | 615190 | 164410 | 50 | 335 | Silurian |
| 21 | 13 | Beltinge BH | 619700 | 167600 | 55 | 564 | Silurian |
| 21 | 14 | Reculver BH | 622680 | 169000 | 58 | 311 | Silurian |
| 21 | 15 | Ebbsfleet BH | 633710 | 161960 | 72 | 420 | Lower Carboniferous |

*Table 22 Profile 21 well data*

**Profile Limitations**

As discussed earlier, the modelled profiles have limitations mainly associated with their 2.5D nature and their irregular orientations. To investigate profile consistency, particularly at intersection crossing points, a composite profile was constructed from a selection of the individual profile results. The composite model profile of Figure 26 comprises parts of nine profiles and includes seven intersection tie points. The residual anomalies shown are those produced by 'stripping' the gravity effect of all Carboniferous and younger sections. Numbers on the model profile highlight significant features introduced to explain the calculated residual anomalies. As expected, there are some discrepancies at tie points but there are no major inconsistencies at the profile intersections. Clearly, a second-pass at the profiles could be made removing or minimising these inconsistencies, but this would tend to hide any objective assessment of the intrinsic modelling uncertainty. Significant residual anomalies are considered to be those showing values greater than 2.5mGal (shaded red) or less than -2.5mGal (shaded blue). Between +/-2.5mGal, values probably represent a combination of low amplitude residual anomalies plus modelling uncertainty 'noise'. As hoped, and despite the inherent model limitations, the profiles appear to have been successful in locating significant residual anomalies associated with authentic deep features which require explanation.



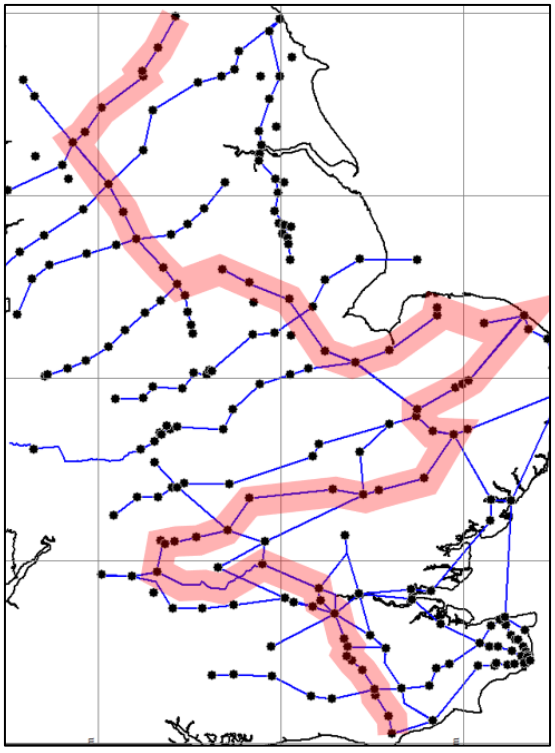



*Figure 26 Composite residual gravity anomaly profile with associated 2.5D models. The profile location is shown by the thick red line on the base map. Significant negative anomalies are shaded blue (below -2.5mGal) and positive anomalies shaded red (above 2.5mGal). Numbers on the model profile highlight significant features:- 1 – Possible ridge associated with the Furness--Norfolk Magnetic Anomaly, 2 – Speculative granite, 3 – Magnetic basement flanking granite, 4 – Newark Granite, 5 – Sleaford Half Graben, 6 – Spalding and Wisbech Granites, 7 – SE flank of N Norfolk Granite, 8 - ?Devonian Basin, 9 – Reading/Sonning Granites, 10 – Profile 17 includes a slightly different Paleozoic subdivision based on seismic interpretation, and 11 – ?Deep Paleozoic Basin responsible for Warlingham Anomaly.*

## Conclusions

A network of gravity and magnetic profiles, constrained by the available well data and seismic mapping, has been constructed and a series of anomalies identified. Many of the anomalies have been previously described but some are new.

Of the thirty-four individual gravity anomalies recognised, fourteen are interpreted to be associated with granitic intrusions. A further eleven anomalies are due to sedimentary basins (some widely recognised, others not) and seven anomalies are associated with known positive structural features. Two anomalies are of uncertain origin. In addition to the individual anomalies, long wavelength features were revealed, especially during the gravity regional background estimation, some of which appear to be related to crustal thickness changes. Several of the anomalies require further, more detailed analysis.

As discussed earlier, the interpretations of the magnetic anomalies on the profiles are more problematic. Of the twenty-eight anomalies, twelve are due to shallow igneous rocks whilst a further seven seem to be associated with older, deeper sources. Six of the anomalies seem to be associated with the margins of the granitic intrusions identified from the gravity anomaly work. A number of the long-wavelength anomalies appear to be associated with regionally-extensive northwest-southeast trending features which were crossed by a number of the profiles.

Many of the anomalies are recognised in one or more profiles. However, an interpretation that links them spatially, consistent with the available geological data, lies beyond the scope of this paper. It is intended to investigate, in two subsequent papers now in preparation, both the spatial extent of all anomalies and their link to the geological constraints, and the relationship between the regional background gravity field and crustal structure.

## Acknowledgements

We would like to thank Malcolm Butler, Bernard Cooper, Andy McGrandle and Dave Shaw for their numerous helpful and constructive comments following review of an early version of this paper. Malcolm Butler kindly assisted with the preparation of Figures 3(a), (b) and (c). Digital potential-field data used were downloaded from the BGS website. BGS is also thanked for providing access to the GravMag Interactive 2.5D interpretation software, on which all modelling shown here was undertaken.

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