PEPPER STREET DEVELOPMENT

INITIAL COMMENTS ON GROUND INVESTIGATION

1. Summary

This Note is a first-pass review of the Ground Investigation reports provided as part of the January 2014 Planning Application for housing development on the former Silverdale Tileries site in Pepper Street, Keele.

The note has been written by Dr. B. Besly, a geologist with considerable and relevant experience in geological field mapping and the geology of the Etruria Formation in North Staffordshire. Dr Besly has little relevant experience and no professional background in contaminated land issues, but his practice as a geologist in the hydrocarbon industry allows him to make informed observations on issues relating to gas migration and degradation of oil shale materials. This Note has been written following collation of public domain and privately held material and a very brief review of the Ground Investigation reports. It should be taken as a basis for discussion rather than as a definitive document.

The principal conclusions of the Note are:

1) The ground Investigation reports cover only two of five distinct sites involved in the proposed development (Tilery and Garage Sites). These are the sites on which building is proposed. The remaining sites (mine tip, open field area and former landfill) form the part of the application that purports to provide the Community benefit, in the form of provision of a "Public Open Space". These have associated with them a number of issues that should have been addressed by site investigation, but which have been ignored.

2) The site investigation of the former garage site deals exclusively with contaminated land issues, upon which no further comment is made. There are no deeper geology issues in this area that have not been covered in the report on the former tilery area.

3) The site investigation of the tilery area has been reasonably thorough. There are, however, significant omissions, notably:

    - failure to identify and investigate the backfilled mid 19th Century clay pit lying between the former tilery buildings and the railway tunnel portal;
    - failure to undertake primary mapping outside the tilery area, leading to
        - underestimation of the extent of development of potentially permeable sandstones in the area of the capped landfill site;
        - failure to accurately constrain a subordinate fault running through the site from NNW to SSE, which forms the eastern boundary of the development of these potentially permeable sandstones;
        - failure to appreciate the significance of the anomalously high gas readings in boreholes WS2 and WS3, which may be interpreted to indicate migration of gas in sandstone bodies rather than through simple soil diffusion;

4) The lack of investigation in the Mine Tip, Field and Landfill areas leaves a range of potential environmental hazards uninvestigated, and lacking in indications of proposed management and mitigation measures, notably:

    - potential for the tip fire to spread into old mine workings underlying the tip, and contingencies for dealing with such an eventuality;
    - water and air pollution issues arising from the use of the Field area to spread and extinguish the burning tip material;
    - lack of understanding of the nature of contaminants in the Landfill, and of the potential for long term migration (100's years) of these into the general environment;
    - lack of understanding of the overall hydrogeological system in the area

5) Ecological issues affecting the possible establishment of a woodland area on the Landfill Site are also identified.

These conclusions are summarised in two maps (Figs. 1 and 2).

2. Background

The Pepper Street development comprises five elements (Fig. 3):

a) A housing development occupying (in general terms)the former Silverdale Tilery site

b) An extension of the same development occupying the Hollywood Garage site.

c) Remediation of the currently burning Hollywood mine tip, as the first of three components in the creation of a "Community Open Space"

d) Conversion of the former landfill occupying the Silverdale Tileries quarry into the second component of the proposed "Community Open Space"

e) Use of the open field lying between and to the west of the mine tip and landfill as a layout area during the mine tip remediation process, followed by incorporation of this area as the third component of the "Community Open Space".

These five elements are hereafter referred to respectively as the “Tilery Site”, “Garage Site”, “Mine Tip Site”, “Landfill Site” and “Field Site”.

The Planning Application supporting documents include two Ground Investigation Reports (hereafter “GIR”) produced by Betts Associates. It should be noted that the GIR’s relate only to the Tilery and Garage Sites.

The Garage Site GIR is mainly concerned with evaluation of contamination relating to the use of the site as a garage: it involves no investigations of bedrock geology. The contaminated land issues covered in this report appear to be standard ones for such a site. As contaminated land issues are beyond the competence of the present author, no further discussion is made.

The Tilery Site GIR presents a reasonably comprehensive account of bedrock geology, drift geology and contamination issues. No investigations are reported regarding the other sites, even though these form key components of the overall development scheme, being intimately involved in the remediation plan, and forming the main element of the Community Gain in the scheme.

The succeeding part of these notes deal only with the Tilery Site GIR and those areas for which no GIR is submitted.

It should be noted that, in addition to the GIR’s submitted as part of the Planning Proposal, Betts Associates have also produced a more comprehensive desktop study of the site, to which reference is made in various parts of the GIR’s [1]. This does not appear to contain any substantive information additinla to tht contained in the GIR’s.

3. History of the site

A history of the development of the site is provided as in Section 3.1 of the Tilery Site GIR. This is based largely on comparisons made between successive editions of the Ordnance Survey 6” and subsequent 1:10,000 scale maps.

The relationships of the component areas of the site to the pattern of excavations at various stages of its use as a tilery are shown in Figs. 4 and 5, taken from the ?1968 and 1877 editions of the Ordnance Survey 6” / 1:10,000 map respectively.

There is an important error in the historical account in identification of former excavations within the Tilery Site and the extreme SE corner of the Landfill Site. While the GIR correctly identifies the position of the clay pit to the NW of the tilery in the 1877 map, it **fails to identify the former presence of a large former clay pit** lying to the south of the tilery at that time, separating the former tilery buildings from the SW portal of the railway tunnel. The importance of this omission is discussed in paragraphs 4.4 and 8.2d.

4. Summary conclusions: Tilery Site GIR

1. The GIR is underpinned by a geological framework derived from the expected public domain sources (mining records, published geological maps). There is no indication that any attempt has been made to check the accuracy of the geological mapping by undertaking field work outside the immediate confines of the Tilery and Garage sites. Unpublished information suggests that the geological mapping is simplistic, particularly with respect to the presence and distribution of sandstone within the Etruria Formation (see additional notes on geology in Appendix 1).

2. The ground investigation has comprised: the drilling of 8 deep boreholes (to 30m) in order to constrain the positions of the previously known faults; the drilling of 15 shallow boreholes for the purposes of groundwater and gas monitoring and identification of presence of contamination; a programme of probe investigation to locate and evaluate the condition of supposed mine entrances; the digging of 19 trial pits to investigate made ground and contamination (Fig. 6).

3. The deep boreholes have achieved the purpose of accurately identifying the location of the major west - east trending Millbank Fault within the Tilery Site, and thus identifying the area of the site underlain by Coal Measures potentially containing shallow old workings. The deep boreholes have made a number of penetrations in the Etruria Formation to the south of the Millbank Fault, but do not, in themselves, improve the accuracy of the positioning of the NNW - SSE trending fault that separates the lower part of the Etruria Formation (underlying the Landfill Site and the western part of the Tilery Site) from the upper part of the Etruria Formation (underlying the central and eastern parts of the Tilery Site). As this distinction has important consequences for the distribution of laterally extensive and potentially permeable sandstone bodies, and thus for possible gas and other contaminant migration routes (see paragraphs 4.6 and 8.2c below and map in Appendix 1).

   The failure to delineate this fault should be regarded as a significant shortcoming in the ground investigation.

4. **The borehole and trial pit programme has failed to fully explore the extent of the 1877 clay pit lying to the south of the tilery buildings or evaluate the nature of its backfill.** The position of the boreholes and trial pits relative to this excavation are shown in Fig. 7. The existence of the former excavation is demonstrated by the succession encountered in deep borehole no. 7, which proved the depth of this former excavation to have been 12.5 metres, and demonstrated that excavation had ceased on encountering a sandstone body having a thickness of 1.7 or more metres.

   The log of borehole no. 7 does not provide a detailed description of the nature of the infill. The contents of this former pit are only otherwise investigated by one borehole (WS10) and three trial pits (nos. 13, 14 and 15), all but one of which are at the very edges of the feature, and none of which are deep enough to provide full documentation of the fill.

   Borehole no. 7 demonstrates that the bottom of the 1877 clay pit was formed by a layer of sandstone. This sandstone layer can be confidently linked to sandstones encountered in the Landfill Site clay pit (see Appendix). These laterally extensive sandstones have the potential to act as gas and contaminant migration paths (see paragraphs 4.6, 8.2b and 8.2c below), and extend at for at least 30 metres beneath the western part of the proposed development.

   The failure to fully investigate this backfilled clay pit means that no information is available regarding the permeability of its backfill and the potential for migration of gas or contaminants within it. The lack of significant gas in borehole WS10 does, however, give some indication that gas migration is not occurring in the fill at the extreme NE edge of this feature.

5. The ground investigation has documented a moderate degree of contamination on the Tilery and Garage Sites. In view of this result, the spatial distribution of sample points might be considered inadequate. This is implicitly recognised in the report, where it is in several places recommended that further investigations should take place. The report on the Tilery Site does not identify, other than in very general terms, the origin of contaminants, and, in particular, does not discuss the extent to which they may be sourced from the Landfill. It is beyond the experience of this author to comment in detail on the contaminated land issues raised.

6. The GIR identifies significant levels of methane in shallow boreholes running along the boundary between the Tilery Site and the Landfill (Fig. 6). **No apparent attempt is made to explain the flow paths that might be involved, or the origin for the much higher methane levels observed in boreholes WS2 and WS3.** The occurrence of these anomalous flows can be related to the presence of permeable sandstones in the lower part of the Etruria Formation. These are known from field mapping carried out in connection with evaluation of clay potential of the Field Site in the 1980's, which have not been recognised in the present ground investigation study (see Appendix). **It appears possible that migration of gas may occur in solution in groundwater within such sandstone bodies, rather than by simple diffusion through soil.** If this is the case, the remediation measures proposed to protect against gas migration may be inadequate, and the area of the site potentially affected by such gas migration is uncertain, since it is constrained by the correct mapping of the NNW - SSE fault referred to in paragraph 4.3.

   The failures to undertake primary mapping of sandstone body distribution, and to fully investigate the nature and pathways of gas migration should be regarded as critical shortcomings of the Tilery Site GIR.

5. Areas not covered by GIR's

No ground investigation studies have been carried out in the Mine tip, Landfill and Field areas. In each case there are significant issues that should be addressed, either of documentation of the nature of contaminants and contaminant pathways, or relating to the practices to be employed in remediation and the management of associated hazards. These are discussed by area in the following three sections.

6. Mine Tip

1. Mapping by the BGS shows that, over *c.* 50% of its area the burning mine tip overlies the outcrops of two major seams in the upper part of the Coal Measures. These seams (the Spencroft and Peacock seams) have thicknesses of 1.35 and 1.4 m respectively in the Kent's Lane shaft of Silverdale Colliery shaft, c. 950 m to the ENE. The occurrence of old workings in the thin Bassey Mine Coal in boreholes Nos 1 and 3 implies that it is highly likely that the thicker and better quality seams underlying the burning mine tip also contain old workings. These coal seams therefore have the potential to be hot (from the fire) and to be permeable to air (as a result of de-stressing and the presence of workings).
   An appreciable risk exists that, if the rock head is exposed during operations to move the burning tip material, potentially uncontrollable ignition may occur and spread into any old workings present.

2. **The ground investigations are completely inadequate with respect to the evaluation of this hazard, and no proposals are included regarding the management of this risk during deconstruction of the mine tip.** A programme of investigation is required along the north-eastern margin of the tip (along Hollywood Lane) to identify in detail the positions and thicknesses of coal seams underlying the burning tip, and the extent of any old workings. Should old workings be present a detailed management programme should be produced to address the risks of management of ignition in these seams. The Tilery Site GIR does recognise the need for additional investigation of the NE flank of the tip

7. Field

1. **It is proposed that the Field Site should be used as a layout area in which the materials from the burning tip will be doused. The proposals contained in the GIR completely fail to address the pollution management issues related to this activity**. These can be discussed under three headings in the following sections.

2. <u>Identification and management of contaminants from partly and fully combusted mine tip material</u>

   Although all previous studies of the burning Hollywood tip have assumed that it is a conventional coal mine tip. This is not the case: the mine principally produced Blackband ironstone, with coal as a by-product. The blackband ironstones contain significant amounts of oil-prone algal material, and both ironstones and coals are interbedded with and overlain by oil shales and cannel coal [2, 3]. Because of the interbedded

nature of these materials and the thin nature of the ironstone seams, the oil shale and cannel material may be expected to form a significant proportion of the waste material from ironstone mining.

The alteration of oil shale by heating (pyrolysis) has been studied in considerable detail in the context of commercial production of oil by retorting. These studies may be regarded as a proxy for the processes that may occur where oil shale is subject to incomplete combustion in a fire. Oil shale pyrolysis is accompanied by the generation of significant organic and inorganic chemical by-products, including (but not limited to) high molecular weight asphaltenes, aromatic hydrocarbons, organic compounds containing nitrogen and sulphur, and organic compounds of heavy metals. In the case that oil shale is completely combusted by burning, the resulting rock residue may be anticipated to act as a source of significant pollutants (soluble salts – notably sulphates, again potentially associated with heavy metals).

No apparent attempt is made in the Planning Proposal to address or quantify these sources of pollution.

3. Management of effluents

The process for extinguishing the Mine Tip fire will require the use of large volumes of water, which may be anticipated to be contaminated by the pollutants identified in the previous paragraph.

No apparent attempt is made in the Planning Proposal to specify the way in which this effluent will be managed. Such management might involve treatment on site or removal from the site.

4. Management of other nuisances

Operations involving manipulation of burning oil shale and coal waste also result in emissions of sulphur oxides, nitrogen oxides, particulates, ozone precursors, and carbon monoxide. In addition, small amounts of volatile heavy metal compounds may be emitted in the smoke and dust generated. The existing, limited emissions of these substances from the burning tip may be anticipated to substantially increase during the remediation process.

No apparent attempt is made in the Planning Application to describe how these possible effects may be mitigated..

It seems that the use of the Field Site for handling and processing the material from the burning tip has not been subject to any critical scientific or technical evaluation (quite apart from any visual or other environmental considerations).

8. Landfill

1. **Although the Landfill Site is likely to house the largest concentration of hazardous materials in the vicinity of the proposed development, the ground investigation studies include only slight consideration of this. This is both surprising and unacceptable**, in view of the potential of this site to act as a source of significant contaminants in the medium to long term (10's- 100's years), and in view of the suitability or otherwise of the Landfill Site for its proposed amenity end use.

2. Questions relating to the landfill that are relevant to the development are as follows:

    a) What materials were deposited in it?
    b) Was it lined in any way?
    c) What is the permeability of the sandstone bodies known or inferred to be present in the sides of the pre-landfill void?
    d) What is the permeability of the backfill southern clay pit of the 1877 survey, whose existence is not recognised in the Tilery Site GIR, and whose fill is contiguous with that of the Landfill Site?
    e) What is the nature of the groundwater table and to what extent, if any, is there any groundwater movement?

f) Is there any evidence of mobility of toxic components of the landfill material, and is there any possibility of slow migration of any such components into the area of the development over the medium to long-term timescale?

Some of these questions are also relevant to the amenity end use of the landfill site itself, but the following questions also attach to that end use:

g) Has there been any release of toxic materials from the landfill into the surface soil of the landfill capping? What is the risk of such release in the future through slow migration in the medium to long-term timescale? Are there any existing contamination hotspots or other nuisances for which a mitigation and management plan is needed prior to amenity use?
h) What is the extent of risk associated with the transfer of such materials into the wider environment, particularly through transfer of soil material resulting from pedestrian leisure use?
i) Do the nature of the soils and drainage of the site render it viable for its proposed Community Woodland use?

3. **The absence of any consideration of these questions in the GIRs is clearly a significant omission.** Answers to some of these questions can be suggested on the basis of unpublished records and field visits to the site. Chief among the unpublished records are:
   - notes made by B. Besly, then a Ph. D student at Keele University, in the course of a site visit to the partially landfilled site on 3rd November 1976, made as part of a geological study of the Etruria Formation;
   - additional local geological mapping carried out in the autumn of 1991 as part of an evaluation of clay extraction potential in the Field Site area;
   - fieldwalking the site in December 2013;
   - fieldwalking the site in January 2014 in company with an environmental scientist..

a) Materials contained within the landfill.

The landfill of the Silverdale Tileries clay pit was carried out in two stages: between 1971 and a date prior to the site visit in 1992 the site was used by Michelin PLC for disposal of "industrial waste"; thereafter the upper part of the remaining void space was filled with general domestic and industrial waste by another operator.

Michelin PLC have been unable or unwilling to provide any information as the materials deposited in the landfill (exchange of emails and phone calls with Christine Reynolds of Corporate Communications Department, Dec 2013 - January 2014). The records reproduced in the GIRs (presumably sourced from the Environment Agency) describe the nature of this fill to include "industrial effluent treatment sludge, process waste, scrap rubber including tyres and wood waste". The waste clearly has a wider scope than the tyres reported in local anecdotal evidence. At the time of the 1976 site visit there was no evidence of the presence of tyres, and the author was informed that the site was being used for disposal of unspecified industrial waste, the hazardous nature of which required his visit to be escorted.

It has to be assumed that the Michelin waste is mainly composed of general waste material related to rubber manufacture. A listing of likely materials is given in the Department of Environment information sheet [4], which includes materials for which there are known **occupational health hazards** [5] but for which there is little easily available information on hazard presented by long-term, low-level exposure.

The records of the later, final phase of the landfill, reproduced in the GIR, are more complete and probably representative. A wide range of materials is likely to be present. This is the phase of fill which is intersected by boreholes Nos. WS4 to WS5: the occurrence of cyanide contamination in borehole WS5 is consistent with the record of disposal of foundry waste as part of the general/industrial waste mix.

b) Lining of the landfill

At the time of the 1976 site visit it was possible to observe a complete succession of the strata forming the western and northern edges of the void. The void was, at that time, approximately half full. **There was clearly no liner in place.**

c) Permeability of the Etruria Formation sandstones and related strata

During the 1970's, excavations in the Etruria Formation were used for the disposal of toxic and noxious waste as it was assumed that the lithologies making up the Formation were impermeable. A number of lines of evidence suggest this generalisation may not always be true.

Sandstones in the Etruria Formation consist of quartz grains and rock fragments set in a green, chlorite-rich clay matrix. Although of low inherent permeability, the flow of groundwater in such sandstones is demonstrated by the routine occurrence of seeps accompanied by oxidation of the chlorite matrix from sandstone bodies intersected by quarrying. Such seepage was noted in sandstone bodies in the Walley's Quarry site in Silverdale when visited in 1977, and may be inferred to be a contributing factor in the unexpected water influx problems encountered during subsequent use of that site as a landfill. In such cases water flow may be interpreted to have been initiated by disturbance of the groundwater table induced by the quarrying. If so, this demonstrates the potential for significant groundwater migration in these sandstones within the 10's to 100's years timescale. Groundwater migration within the permanent water table may, however, also be inferred from the occurrence of late diagenetic fabrics in near surface sandstones (*e.g.* samples from the Silverdale Colliery access drifts described in Besly's PhD thesis [6], pp. 221-222 and Fig. 174).

The potential permeability of other lithologies on the Etruria Formation is less well known. However, the description of the strata made during the 1976 site visit recorded open joints coated with limonite and a black pigment (?manganese dioxide) in a silty mudrock at some depth in the claypit face. The occurrence of these pigments demonstrates active fluid movement and oxidation in non-sandstone lithologies.

Final evidence of considerable water migration within the Etruria Formation at some depth below ground level is provided by the very considerable water ingress and mineral precipitation in the adjacent railway tunnel, which is excavated in Etruria Formation for its entire length [7].

d) Permeability of the fill of the 1877 southern claypit

No information is available regarding this, other than the simple description of the fill ("grey and black shale with ash and bricks") given in the Tilery Site GIR borehole descriptions.

e) Nature of groundwater table and extent of groundwater movement

No information is available (but see also paragraph g below).

f) Extent of migration of toxic materials other than gas, and potential for this to occur in the long term.

No evidence available.

g) Evidence of release of toxic material from the landfill.

Examination of the surface of the landfill shows limited colonisation by trees in the 20 years since the landfill was capped. While this may in part be attributed to grazing, the stunted and unhealthy nature of the hawthorn trees that have become established suggests high level of soil toxicity. In particular, the crown and western flank of the landfill show areas of partially bare soil, clearly visible on the satellite image (Fig. 8), with local colonisation by lichens only. This again suggests that toxic material is leaking from the landfill. At various points around the margins of the sloping capping are concentrations of sedge, hard rush and soft rush. These suggest local outflow of groundwater through the capping material. The occurrence of both types of rush, indicative of alkaline and acidic conditions respectively, may point to chemical contamination of the groundwater by the contents of the landfill.

h) Risk of outward transmission of contamination from the Landfill Site if used as a public amenity area.

In the absence of a GIR covering the Landfill Site and containing comprehensive documentation of the extent and nature of contamination this cannot be assessed.

i) Do the soils and drainage of the Landfill Site make it suitable for the envisaged end use as a Community Woodland area?

Following closure of the site, the landfill has been covered with a clay cap of unknown thickness, assumed to be composed of locally sourced Etruria Formation mudstone. Over much of the site this forms a thick glutinous clay 'topsoil', characterised by standing water and extensive moss cover except in areas of steepest gradient. Tree recolonisation is limited to willow and stunted hawthorn, except near the southern margins, where proximity to the original land surface coupled with steep gradients allowing surface water run off may be inferred to have allowed the establishment of a more diverse range of trees. Over much of the area of the landfill it is unlikely that a diverse woodland would become established over any foreseeable timescale. Planting of such trees, for instance oak, would require undertaking of considerable drainage works and excavation of holes, neither of which would be desirable in the vicinity of the mixed waste material known to be present in the shallowest part of the fill. In these circumstances the most that can be hoped for is the establishment after a significant time period of a willow-dominated open woodland of low species diversity and ecological interest. An example of such a woodland, developed on a contaminated industrial site is to be found on the site of the former Ramping Pit coal mine (c. 1 km to the north at GR 380575,346960), where a damp and uninteresting willow-dominated woodland has become established since the abandonment of the mine sometime prior to 1900. Evidence from the 1945 aerial photograph (Google Earth) shows that little of this growth occurred in the first 40 years following abandonment. This suggests that a detailed management plan is required if the proposed woodland is to become established within a reasonable time frame.

References

[1] Betts Geo-Environmental Land off Pepper Street Desk Study Jan 2013 12HDS002/DS.

[2] Gibson, W. 1901 Geology of the North Staffordshire Coalfields. Memoirs of the Geological Survey, England and Wales: see pp. 219-224

[3] Rees, J. & Wilson, A. Geology of the country around Stoke-on-Trent. British Geological Survey, memoir for 1:50,000 Geological Sheet 123: see pp. 47-51

[4] Department of the Environment, 1995 Industry profile: Chemical works – rubber processing works (including works manufacturing tyres or other rubber products), 15 pp.

[5] Occupational exposures in the rubber-manufacturing industry. IARC Monograph 100F

[6] University of Keele, 1983

[7] See text description and accompanying photos at http://www.forgottenrelics.co.uk/tunnels/gallery/silverdale.html

APPENDIX

BRIEF DESCRIPTION OF THE GEOLOGY OF THE SITE

Geological mapping employed in GIR's

The bedrock geology mapping used by Betts Associates in their GIR is derived from the published solid geology map (Stoke-on-Trent, British Geological Survey [BGS] Sheet 123). This is shown relative to the site boundaries in Fig. A01. (The poor quality of reproduction derives from the map having been enlarged from the 1:50,000 scale).

The overall site lies on a southward slope developed on units of the Upper Westphalian Coal Measures (shales, coal seams and ironstone seams) and Etruria Formation (red mudstones used as brick clays, and sandstones). It is divided by faults into three segments.

1) A WNW – SSE trending, southward throwing fault (the Hollywood Fault – formerly named as the Millbank Fault) fault separates a northern outcrop area of Coal Measures from a southern outcrop area of Etruria Formation.
2) A NNW – SSE trending, eastward throwing fault or complex of faults (un-named) further divide the Etruria Formation area into:
   - a western section in the lower part of the Etruria Formation, occurring under the Field Site, the Landfill Site and the western part of the Tilery Site; and
   - an eastern section in the upper part of the Etruria Formation, occurring under majority of the Tilery Site and the Garage Site.

In the BGS map the outcrop positions of a number of coal seams are shown to the north of the fault. The outcrop are of the Etruria Formation is marked as comprising uniform occurrence of mudstone, apart from a single band of sandstone mapped running through the Field Site to the WSW of the Mine Tip Site.

Additional comments on solid geology

Additional geological information was gathered in the course of PhD studies and work undertaken in context of evaluation of clay quarrying potential. From a mapping point of view the most useful information has been derived from 1991 observations of temporary excavations associated at the west side of the Field Site and in Holly Wood; the nature of the breaks in slope in the Field Site; and temporary exposures along the western margin of the landfill clay pit prior to its final infilling. These have allowed construction of a geological cross section through the Landfill Site. The resulting map and cross section are shown in Figs. A02 and A03.

It should be noted that this map is based on the 1960's hand-drawn version of the BGS 6" scale geological mapping, in which the position of the Hollywood Fault is incorrectly shown some 40 m to the north of its now established position.

1) The temporary exposures and pattern of breaks of slope in the field allow confident mapping of a number of laterally persistent sandstone bodies additional to the one sandstone mapped by the BGS, at a higher stratigraphic horizon within the lower part of the Etruria Formation.
2) The pattern of working within the landfill clay pit, as revealed by the OS maps, clearly demonstrates the continuation of this sandstone body through the pit. The clay pit was worked in two lobes, separated by a pronounced ridge (Fig. 4). Construction of the cross section shows that ridge corresponded to an area in which the clay workings in the southern lobe had encountered the top of this sandstone. As in the 1877 excavation (see paragraph 4.4), it may be inferred that the presence of this thick sandstone led to the discontinuation of excavation of the southern lobe of the clay pit. Clay extraction continued in the northern lobe, in the layer of clay underlying the sandstone, leaving the observed ridge. The extension of tis sandstone body into the Tilery Site is proved by the succession encountered in borehole no 7 of the present site investigation.
3) The sandstone bodies in the Etruria Formation, although in general terms laterally extensive, are locally impersistent or heterogeneous in their internal make-up. Sandstone body 'C', observed in the topmost part

of the landfill in 1991 appears to have passed laterally into a siltstone bed in the section measured in 1976 at a deeper level in the clay pit. The top part of Sandstone body 'B', forming the base of the section observed in 1976, is very fine grained and interbedded with silt or mud material. This heterogeneity is typical of the Etruria Formation (extensively documented in Besly's thesis [4]).