To the Members of the London Underground Railway Society.

WRITTEN BY JOHN PATTINSON THOMAS AT THE COMMENCEMENT OF THE 80th YEAR OF THE TUBULAR RAILWAYS SERVICE OF LONDON

October, 1969.

THE LONDON BLUE CLAY AND THE COMING OF TUBULAR RAILWAY TRANSPORT

Introduction.

1. This phenomenal unyielding impervious strata of tertiary loam, this deep-down London clay upon which stand great buildings and institutions of the Metropolis, is conspicuously the tenement of the cast iron tunnel system that forms the ubiquitous tubular railways of London - this invaluable system conveying 2 million passengers each working day upon their several occasions that largely knit together the business and cultural life of the city.

Beginning and growth of system.

2. The Jubilee year of H.M. Queen Victoria in 1887 - 82 years ago - saw the lifting of the first spadeful 52 feet beneath King William Street, E.C., terminal of the first electrical tubular railway extant, the resolute City & South London Railway. Two years later this virile 4-mile line came into public use. Thus on November 5th next (1969) it begins its 80th year of public service. In this octogenarian era the tubular system has completed 90 deep tunnel route miles, including the 2-mile Waterloo & City deep line of the Southern Railway, all in this somewhat mysterious clay. Such route mileage, were the tunnels in single file, would extend to 200 miles of standard 11'8$\frac{1}{4}$" diameter - latterly increased to 12'0" - and outstrip the distance from London to Liverpool (this 200 miles inclusive of tubular sidings, avoiding lines and multiple junctions, and 150 escalator stations having from 2 to 6 platforms).

3. Little could these heaven-sent engineers of this system of urban travel in London - Baker (Sir Benjamin of Forth Bridge fame and other great works), Greathead (inventor of the cutting shield that made excavation safe and strong), Mather (of Mather & Platt, Electrical Engineers of Manchester), and Mott (of Messrs. Mott, Hay & Anderson, Consultants to the Underground Railways) - inspired as they were, have envisaged the capacity

and the advancement of their "progeny" to build 200 miles of cast iron tunnelling and the amazing excavation of 7,250,000 tons (seven million two hundred and fifty thousand tons) of blue clay to provide the daily service in 1969 of 4,000 tubular coaches and 20,000 employees conveying some 800,000,000 passengers per annum, including the new masterly electromagnetic automatic equipment of the Victoria Line (Line No.7 in the Underground establishment) and the District and Metropolitan cut-and-cover system. Upon the completion of the Streatham extension (and hoped-for extension to Croydon, when still the shortest of any of the Underground lines) and the Aldwych-Waterloo branch, and also the contemplated Fleet Line which, 'inter alia', provides underground transport direct into the West End from the county of Kent for the first time, the volume of underground traffic could well reach 1,000 million per annum, 80% travelling through the clay and 20% the District and Metropolitan cut-and-cover system.

The Victoria Line is a great acquisition to the system, the Parliamentary Bill for which was piloted through by Sir John Elliot, then Chairman of the Transport Board, against the difficulty of the financial climate of the country of that day - indeed a great achievement to have succeeded at so critical an era.

Need for further development

4. This cannot possibly be the end, for there remain acutely over-burdened areas without underground facilities at all, such as Millbank, the south bank of the River (parallelling the Strand), Knightsbridge-Barnes via Kensington Road, and Victoria Park-Dalston-Hackney. Of course, it will at once be said "What about the great cost of all this excavation and equipment of this system?". This cost has in fact grieviously gone up from about £1 million per route mile before the second world war to about £6 million, and would be even more in difficult expensive subaqueous patches, such as for instance between Elephant and Camberwell, mostly in the Greenwich and Reading gravelly beds, and also where proximity of more and more foundations of great buildings must be especially safeguarded. Costs are still going up and up: relative economy is gained therefore by proceeding now with this exclusive means

of satisfactorily shifting London's paramount traffic.

5. The public has by long experience against fog, Royal and Civic functions and many other forms of road delay, acquired utmost faith in the tubular form of transport. Not so the services by road: the public has lost faith in this formidable and irrepressible product of the internal combustion engine as applied to the congestion of to-day's thoroughfares such as has come about in the craze for speed and independent movement by wheel rather than foot. Hence the proliferation of vehicles that choke the streets. The tubular system is the way of escape from this. What can be more costly and exasperating than loss of productivity and business caused by the "hang up" of road services, the rule rather than the exception. London's progress will be in doubt until this second plane of traffic in the clay is much more generally understood by Parliament and when the public are enabled to go about their business with a fair sense of certainty and economy.

Appreciation of work of pioneers

6. It may not be out of place to offer a word of tribute to outstanding engineers who made available this underground system of travel, now a great part of London's life. Their prophetic vision is now perhaps a commonplace. The pioneers and inventors who brought these amenities to us are almost forgotten. In the pace and pressure of life to-day this may be understandable: none the less, such aids to urban travel and triumphs of civil engineering and electrical science led by great men might be remembered from time to time.

7. In this phase of their work no experience elsewhere was available. Nothing of the sort had anywhere been attempted. The District and Metropolitan cut-and-cover systems already in vogue held no guide to 100-ft. deep railways, invaluable as these subsurface lines are. The first electric tramway did not operate in London until 13 years later than the tubular line. The traffic in the West End was at that period moved almost entirely by the horse and the mule. The courageous engineers were left to their own devices and resources. They felt apprehensive of public reaction to travel of troglodyte significance. Their fears were not without foundation, as until the new line had proved by good running and in the depths fairly well ventilated, lighted, speedy and safe, the public were naturally hesitant. The sequel, however, was that the line was soon appreciated and, surprisingly enough, paid 3% interest upon its Ordinary Stock, hastening

forward the extensions to Clapham Common, to Kings Cross and Euston, soon to connect with the Hampstead and Highgate Lines. Originally opened at the flat fare of 2d. any distance. Upon wet evenings 3d. was charged. The public raised no objection to this penalty to escape a wetting. At that time trams and buses were open-topped. Not until 10 years and 20 years respectively afterwards were they weather-proofed. The cockney described them as "the tram or bus with the lid on"!!

Form of locomotion adopted

8. This City & South London Railway was originally intended to be equipped with cable traction such as powered the then Edinburgh Tramways. Cable drawings were prepared and equipment about to be requisitioned and then, out of the blue, came a wonderful and surprising proposal from Messrs. Mather & Platt to prepare a scheme of electrification based upon the then "3-wire" D.C. 600 v. principle of distribution of energy and, moreover, to build fourteen 100-h.p. locomotives. This forthright offer proved a godsend. The cable idea was soon quashed and the first electric deep level railway in the blue clay had arrived. Grateful indeed must the traction industry and the public be to this far-seeing Manchester Company, who have on other occasions come first in the field in electrical and mechanical application to problems of the day. Their D.C.600 v. locomotives, improved from time to time, remained for 38 years in continuous service, until the London Underground Company took over and enlarged the tunnels to standardise through working, adopting the Sprague American multiple unit system of electric locomotion now the generally accepted D.C. system of traction brought into the United Kingdom by the Central London (2d. Tube) Railway Company in the year 1903.

Disposal of Clay in excavation

9. What has become of this vast disposal of clay in the building of some 200 miles of tunnel in these 80 years? The answer is that in the earlier years of pick and shovel excavation the large and heavy lumps were too unhandy for economic puddling. The whole of the soil was disposed of by lorry in to disused pits, levelling deep depressions, and used sometimes in railway embankments but not particularly successful in this. It is said that some clay was taken to sea and dumped. Latterly the excavation, by study and

achievement of very highly mechanised and ingenious rotary cutting devices, is in much smaller lumps, enabling economic puddling. Out of this came special treatment in manufacture of black bricks, now much in demand. One of the leading brick companies in Surrey specialises in this. It is understood that all the removed clay of the new Victoria Line has been handled in this way except for small portions retained for puddling and hermetically sealing the iron tunnels into the clay surround. Thus what in early days was a drudgery and nuisance has by scientific and mechanical application become today a useful commodity in building of all kinds.

Foundations of Multi-storey erections in vicinity of tunnels.

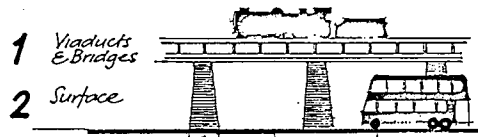
10. The question has been raised of possible trouble to these tunnels from the weight of modern 30-storey erections. There need be no fear on this score at all as the weight of these buildings is carried on pile foundation and taken down to depths below and away from the Tube, so that no weight directly falls upon it. The foundations of the large buildings now going up in so many places in London will, however, add to the difficulties of engineers in planning new railways so urgently needed to counteract the stagnation of the traffic upon the streets and the roads above. How wise to get on at once in building more Tube lines before the door is closed to needed routes by these obstructions.

11. The writer of these lines has seen cast iron segments removed for investigation after 48 years 'in situ'. The clay and the segments proved to be in most perfect condition, quite unchanged, and were returned to their original setting. Thus the evidence of the durability of the system of deep tubular tunnelling; and what is more, the cost of day-to-day maintenance of this system is almost negligible, far less than that of brick tunnels of the cut-and-cover systems or of any other system of railways permanent way.

Diameter of tunnels

12. The initial diameter of tubular tunnels was 10'6" and proved to limit the size of coaches beyond what the public cared for. Investigation of varying designs and experimenting with "mock up" coaches disclosed how greatly the roominess of cars was improved by a tunnel 12" greater in diameter than the original 10'6", whilst with an increase of 14¼" both cars and bogies were improved surprisingly, and this established

THE FOUR PLANES OF URBAN TRANSPORT IN LONDON



1 Viaducts & Bridges — Suburban Lines

2 Surface — Buses, Coaches + Taxis

3 Sub-Surface Cut-and-Cover — GRAVEL — District & Metropolitan — 20 FEET

4 TUBULAR Railways conveying 2,000,000 passengers daily — Approx. 90 route miles in clay — LONDON CLAY — 30-600 FEET

Deepest Station - Hampstead — 200 Feet

TERTIARY LOAM.

CHALK — 10,000 FEET BELOW SURFACE

UPPER GREENSAND

GAULT

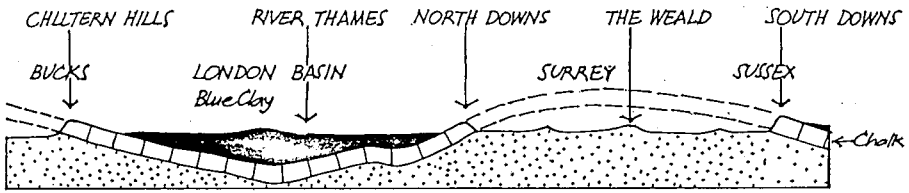
ILLUSTRATION INTENDED TO RECORD THE BEGINNING OF THE 80TH YEAR (NOV. 1969) OF THE CLAYBOUND IRON TUBULAR RAILWAY SERVICE IN LONDON - IN 1890 - 4 ROUTE MILES
TODAY - 90 ROUTE MILES
& SOON - 100 ROUTE MILES

J.P.T. 21-10 69

DAVID HOLLIS F.R.I.C.S.

J.P. THOMAS. F.I.E.E, Ch. Eng. M.Inst T. - OCT 1969

THE LONDON BASIN & THE BLUE CLAY



SECTION FROM NORTH TO SOUTH - NOT TO SCALE

J.P.T.
D.C.H 1969

the 11'8¼" diameter tunnel as the economic size for London. Any diameter larger showed little advantage, and the cost of tunnelling of course increases as the square of the diameter. Thus the 11'8¼", latterly increased to 12'0" by mechanical tunnelling, is now appropriately standardised in London and will not undergo any change in this respect in so far as experience can show. Though part of the system has adopted concrete segments, cast iron is the form of tunnelling generally preferred.

Nature of the blue clay

13. The blue clay is uniform in lithology - a monotonous blue grey substance which weathers when exposed to sun and air into a yellowish brown. Of course, in the tubular system it is never exposed to weather conditions and retains there its blueish-brownish shade. The greater part of the clay is unfossiliferous though in rare sections there are fossil shells and forms of fishes and curious animals, together with plant remains. The latter are indicators of climatic conditions much warmer than at present. The whole assemblage is characteristic of the tropical rain belt and is estimated to have been deposited in about 100 fathoms of water. As the chalk seas of the Cretaceous Period retreated they left numerous fresh water lakes. The largest of these lakes centred on London and is known by geologists as the London Basin. (See diagram attached). About 60 million years ago the sea broke into this lake, heavily pouring in the silt and sediment of clay from adjacent land. Foot by foot the clay gradually built up to great thicknesses and hardness and toughness as seen in excavations in London today. (Quote from Historical Geology by A.K.Wells).

14. Is the London clay unique? Only in the fact that it is geologically the youngest clay formation existing today. The nearest in age that bears resemblance to it is the Bovey Tracey clay in Devon, probably 40 million years old. The strength is in its compactness and not due to any cementing agent. The chief components are clay minerals. These in compaction lie down flat together and, overlapping, make a strong structure. In addition, there is some re-crystallization of the minerals which helps to lock the clay together into its present invulnerable state. The thickest deposits occur in North and Central London, about 300 feet thick.

Area of blue clay

15. The strange thing in the deposits is that the area practically coincides with the requirements of the system of London's tubular railways. This clay is a "tidy lump" extending about 25 miles east to west, 22 miles north to south and its centre is about Holborn. Outcrops of shallower blue clay occur beyond these mileages and are found as far east as Chelmsford and Cambridge and westward as far as Bagshot, Reading and Poole in Hampshire. The great bulk, however, is providentially in the immediate London region of required buildings and that of the permanent way of the tubular lines.

Method of measuring depth

16. Geologists sometimes measure that depth in fathoms since the whole area was once under the sea. Thus the deepest tubular station is under Hampstead Heath, 30 fathoms, the shallowest at Queensway, 6 fathoms, and the average of all the stations is 9 fathoms, whilst there are many stations in the West End of 20 fathoms, and the cavity of some of the escalator tunnels and stations reaches 36 ft. diameter. To the public depth matters little, since in the higher speeds of escalators, travelators and elevators the time in vertical motion is a matter of a minute or so, wherever the station may be. Whatever the depth, while the passengers are taking a good look at the attractive "briefs" upon the escalator framework the time seems shortened to a few seconds. Depth is not of the least account to the passengers so long as they "feel" they are going ahead speedily - and here lies the psychology which has its part to play, and an invaluable concomitant of the administration of this service.

Advantage of escalators beginning and ending at street and platform levels.

17. Of course, if all escalators began and ended strictly at street and platform levels, as at Baker Street Station (Bakerloo Line) and the upper flight at Charing Cross (Bakerloo Line), the tubular system would be of greater help to the short distance and elderly and infirm passenger, and more lucrative. Having these examples of Baker Street and Charing Cross in mind, this modern plan should be adopted at future stations regardless of difficulty.

Short distance traffic

18. Before this new age of motorised chaos the short distance mile to mile-and-a-half traffic had always been looked upon as the prerogative of the bus. Before the first world war the Bus Company thrived upon the 1d. fare (60% of the traffic) and paid 12% upon its capital . All this is quashed in this new age, and now the short distance traffic - the "rabbit" traffic as it was called by busmen in the distant days - upon the Underground Railways has moved up in the last two decades from 9.99% to 23% today. This startling change in habit imposes upon the Transport Board far greater operating cost, since the capital commitment of the bus is a mere cipher compared with the huge capital absorption of the Underground Railways. The short severe minimum fare peaks upon the railways impose great strain upon train service requirements yet the Board, which is a public undertaking, must accept this unremunerative traffic upon the railways. The frustration of short distance bus travel and the milling crowds upon the pavements have compelled recourse of pedestrians to the Underground service for short journeys previously made on foot or by bus in the more placid age when urban transport paid its way, except Tramways - and the latter includes the London County Council predecessors of the Greater London Council, who never equated all of the financial charges and sinking fund incurred by their costly conduit and plough system of electric current collection, which every other Tramway Company in this country decided not to adopt.

Advantages in excavating in London blue clay

19. Whilst the London clay has proved very suitable material in which to excavate tunnels one should make it quite clear, of course, that an underground system could be excavated in any rock, whether rather soft (comparatively) like the blue clay or hard such as the rock beneath New York, where very considerable blasting was necessary. What matters is the expense. The cut and-cover routes in so extensive and congested and now built up city as London postulates most acute inconvenience to frontages and an expense likely to run into perilous millions - may be ten times the cost per mile of the deep tubular system. There is no problem in cut-and-cover that cannot be dealt with by engineering science if costs do not matter, but who would undertake the necessary

expense when the present tubular system in the clay has by all standards proved itself eminently equal to the London task, and even more so by the extensions and proposals under way.

20. It is important to bear in mind that a mile of tubular railway at £5 million per mile is the progenitor of a mile or more in the open at one half of this cost.

Major projection of lines

21. The first major projection from clay to surface was that of the Bakerloo Line to Harrow and Watford - 8 miles tubular, 13 miles open tracks of the then London & North Western Railway, junctioning at Queens Park Station. This far-seeing innovation came in the year 1910 from that erudite and intuitive mind of Albert Stanley - later Lord Ashfield, Chairman of the Underground Railways - and from Sir Frank Ree, Chairman, London & North Western Railway, and stimulated by Herbert A. Walker, then Superintendent of the Line and later Sir Herbert, General Manager of the Southern Railway, and who upon other occasions aided the projection of the Underground into Main Line suburban territory. The first world war delayed the Elephant-Watford work, yet this "bi-tubular" line opened for service during the war, in 1917, and was conspicuous in having the first automatically controlled centre doorways to the cars, the earliest forerunner of the automatic side doorways now in general use and having 14 feet of such controlled doorways upon each side of the car, which system improved the capacity of the Underground Railways by 30% by more uniform use of car space and shortened station stops.

22. This "bi-tubular" system into the hinterland became the accepted practice and enabled the railway extensions through the clay to be projected into five counties surrounding London, namely Herts, Middlesex, Surrey, Essex and the borders of Bucks, and soon, it is hoped, Kent to make the half-dozen and for the first time bringing that area right into the West End without change of carriage and projecting to some 120 miles of route in the open, bringing the total route miles of the whole "bi-tubular" system to about 370. Expressed in single miles, including operating sidings and stabling facilities, the total becomes some 650 miles, all of this in the service of the Underground system - about

one-third located in the blue clay.

Conclusion

23. Thus may we salute the blue clay of London, enabling the distribution of a volume of traffic equal to one quarter of this vast London population daily and the employment of an army of able and courteous employees in this great service.

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Attached: Proforma diagrams:-

(1) London's four planes of collective transport.

(2) The London Blue Clay Basin.

With acknowledgement of much appreciated help in compilation by the Geological Departments of London University and Leicester Univeristy and V.A.M. Robertson, Esq., formerly Chief Civil Engineer of the London Transport Board and the Southen Railway.

P.S. To those who may wish to study the geology of the soil there is legion of literature. "The outline of Historical Geology" by A.K.Wells provides excellent treatise. (Allen & Unwin)