

THE ORIGINS AND DEVELOPMENT OF THE BRITISH COPROLITE INDUSTRY

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(with geological notes from T.D.Ford)

Abstract: In 1842 a new extractive industry started in the Pliocene Red Crag cliffs of Felixstowe, on the southeast Suffolk coast. It was variously called coprolite digging, fossil digging, fossiling or fossiliting and was a branch of agricultural mining which supplied the nation's manure works with calcium phosphate. This was a raw material much needed in the manufacture of superphosphate - the world's first artificial fertiliser. Over the next seventy years or so the diggings were to have a significant social and economic impact as they expanded westwards across many parishes on the Deben and Orwell estuaries and on to the Lower and Upper Greensand in parts of Norfolk, Yorkshire, Cambridgeshire, Bedfordshire, Hertfordshire, Buckinghamshire, Oxfordshire, Hampshire and Kent. There were comparable workings in the Greensand deposits in Belgium, France and Russia.

INTRODUCTION

The ending of the Napoleonic Wars with the defeat of the French at Waterloo in 1815 brought a period of peace and prosperity to Great Britain. Its population doubled over the first half of the century. Market towns and cities expanded rapidly on the coalfields and alongside the major rivers, canals and railways. The exodus from the countryside to the urban areas resulted in an enormous demand for accommodation and food.

One can probably remember from one's schooldays Jethro Tull's seed drill, Lord 'Turnip' Townshend's four-course crop rotation method and the Earl of Norfolk and other agriculturalists' experiments at crossbreeding that produced enormous pigs, cattle and sheep. But other experiments were going on with plants and soils. The application of science and capital was being expended on agriculture as it had been on manufacturing. This was termed "High Farming." Developments in analytical chemistry allowed scientists to discover that phosphate was a major nutrient in plant growth. The search began to discover new supplies.

In 1828 a rock phosphate, called phosphorite, started being exploited in Ontario, Canada. Chemists had found its value as a fertiliser and samples were tested in Great Britain. Humboldt, the German explorer, returned to Europe with details of the South American coastline and his report led to the European's "discovering" the use of "huano" or guano. This was an accumulation of thick deposits of phosphate-rich bird droppings with impregnated discarded fish carcasses and bird skeletons on the Chincha Islands off the coast of Peru. Shipping companies started to import it into Liverpool docks from 1838 where it was sold it at up to £12 per ton. This was much more expensive than crushed bones as fertilizer but a successful advertising campaign in the agricultural press led to its widespread usage.

Animal manure had been used successfully for thousands of years but there was not enough to meet the demand. Scientific tests proved that soot, shells, fish, seaweed, blood, bones and even rags from discarded wool and cotton clothes were useful in increasing yields. Maybe one can remember the rag and bone man? It was the waste product of the knife manufacturers in Sheffield, however, that sparked the interest in bones. It was found that the shavings from their knife handles proved a very effective fertiliser when added to the soil. The corn mills used by the agricultural suppliers were not able to meet the demand

for bone meal and this led to the setting up of bone manure works. Their most popular products were half-inch bones. These were burnt or crushed and added to the soil as bone meal.

However, the bones from the knacker's yards were insufficient to meet the demand of the nation's manure manufacturers, a factor that led to the import of dried bones. There were reports of cargoes of mummified cats from Egyptian pyramids and sun-bleached bones from the North African desert and the Argentinean pampas. The battlefields of Leipzig, Waterloo and the Crimea were scoured for their bones and even catacombs in Sicily were emptied. "Great Britain is like a ghoul, searching the continents for bones to feed its agriculture ... robbing all other countries of the condition of her fertility" (quoted in Keatley 1976).

By 1839 the bone business was worth £150,000 per annum and about 30,000 tons were being imported annually. The *Gardeners' Chronicle* and *Agricultural Gazette* gave detailed accounts of the efficacy of these new manures. However, tests showed that crushed bones were almost insoluble. It took a long time for them to decompose and for their mineral potential to be absorbed by the plant roots. Bones were also expensive and the machinery for grinding them had not been perfected.

ENGLISH COPROLITES AND THEIR HISTORY

An unusual alternative was fossils. Millions of tons of them were found in South East England. The term used for this fossil bed, when it was first discovered, was "coprolites." From their name some people thought they were a source of copper, others that they were human bones, the droppings of fish, lizards, wild beast and even dinosaurs. The main reason for the confusion was ignorance, even in the spelling of the word. This was due to variations in local dialect and the poor literacy of the census enumerators. Fourteen different variations have been found in the 1861-1891 census data. They include coprolite, copperlight, copper light, copperlite, coupperlite, copralite, corporolite, coproilite, coprelite, coperlite, coporlite, coparlite, coprolithe and coperalite. No wonder there has been confusion over their origin.

It was Rev. William Buckland, the Dean of Westminster and the first professor of Geology and Mineralogy at the University of Oxford, who coined the word Coprolite. It came from the Greek

"kopros" meaning dung and "lithos" meaning stone. Dung stone - fossilised droppings! In 1829 he went on a geological excursion to the Dorset coast at Lyme Regis. Examining the clay and sands exposed by a recent landslip he found the complete fossil remains of an *Ichthyosaurus*. Unusually, it also included its fossilised stomach contents.

In 1842 after Rev. John Henslow, the professor of Botany at St. John's College, Cambridge, had been given a living in the Suffolk parish of Hitcham, he went on a trip to the Victorian watering hole of Felixstowe. There had recently been a landslip in which he found some interesting fossils in the newly exposed Suffolk Red Crag in the cliff faces. There were loads of coprolites or bones. From their smooth, brown, elongated shape he took them to be similar to those of the *Ichthyosaurus* discovered by Buckland. Henslow suspected that, like animal manure, they would be useful as fertilizer once they were ground to a powder. He was probably aware from reading about Suffolk's history that the shelly Red Crag had been used on the fields for generations.

Experiments on Buckland's coprolites by dissolving them in vitriol, i.e. sulphuric acid, showed them to have a high phosphate content. John Bennet Lawes, a Hertfordshire landowner, experimented with different manures on his estate in Rothamsted. He too dissolved animal bones, the mineral phosphorite and Felixstowe coprolites in vitriol. The resulting mixture he called "super phosphate of lime". His tests showed that it was soluble in water and that the plant roots could rapidly absorb it. This "super" as it came to be known, was the world's first chemical manure and its application so dramatically increased his turnip yields that he knew it would be much in demand not just by Great Britain's farmers but those in the rest of the world. They were eager to improve supplies of winter fodder to avoid the large-scale slaughter of animals after the harvest was in.

In 1842 he patented his "discovery" and set up the "Lawes Artificial Manure Company". He bought a plot of land on the Thames at Deptford and had a large chemical manure works built that was capable of producing up to 200 tons of superphosphate a week. He sold his "super" at up to £7.00 a ton and took legal action against other manure manufacturers to ensure that anyone who wanted to use his patent had to pay him five shillings (£0.25) for every ton they produced.

What sparked the take-off of the coprolite industry was a paper Henslow read in Cambridge in 1845 to the British Association for the Advancement of Science. It dealt with the potential value of coprolites to the nation's farmers. Suffolk manure manufacturers like William Colchester, Edward Packard and Joseph Fison took interest. Like Lawes, they made arrangements with landowners in Felixstowe and neighbouring parishes on the Suffolk Crag to have the fossils dug up, washed and transported to their works in Ipswich. They only paid a few shillings a ton royalty for the fossils which gave them enormous profits.

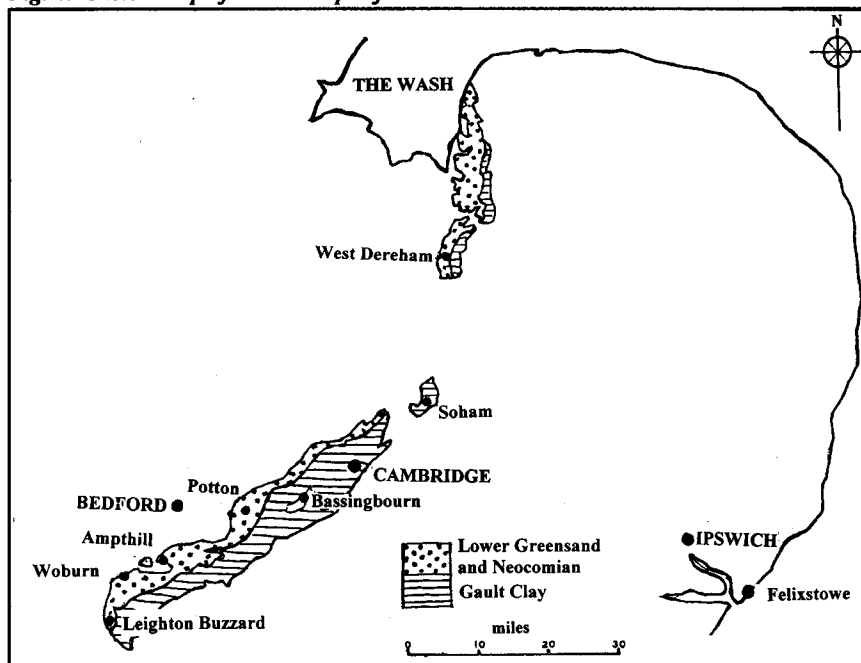
By 1846 a similar fossil bed had been identified in Burwell in the northeast Cambridgeshire fens. Its discovery was related to an important fenland occupation,

locally called "claying." This involved the digging of small pits through the "moor" or "bear's muck," as the bog-earth was called, to reach the clay. This lay between two and ten feet (0.74m. - 3.7m.) below the surface. Wearing waterproofed boots the diggers would use a sharp, cutting-edged shovel to dig through the peat, a light wooden scoop to get rid of drainage water and an axe or "bill" to excavate the clay beneath. The top metre of clay was thrown to the sides of the pit and then mixed into the peat. Henslow was shown some of the fossils that the diggers had unearthed and told the farmer that he had discovered a treasure, a food-mine!

The farmer bought eleven acres of waterlogged fen and sold it to William Colchester for £1,000. Realising almost £100 per acre was a phenomenal profit, given that agricultural rents ranged at that time from about ten to forty shillings (£0.50 - £2.00) an acre. The following year Colchester was raising 500 tons a year and exploration began in a big way. Over the next few years articles about this new source of phosphate and the fossils found in the bed appeared in the agricultural press, as well as in geological magazines and journals. The description of the fossil beds found at the base of both the Upper and Lower Greensand prompted their exploitation along the Wey Valley near Alton in Hampshire.

By 1849 the owners of brickfields in Cambridge started selling what they had previously considered "troublesome annoyances" and over the next decade coprolite works opened in many of the open fields in and around the city. As more and more businesses joined in the rush for manures, demand for coprolites rose. Royalties paid to landowners increased to between seven and fifteen shillings (£0.35 - £0.75) a ton in the early 1850s. They depended on a range of factors. These included its depth, extent, continuity of the seam, the angle of dip, its cleanliness, proximity to a water source, road, wharf or station, the volume coming on to the market, knowledge or ignorance of current prices and, inevitably, nepotism - how well the manure manufacturer, farmer or coprolite contractor knew the landowner.

Fig. 1. Sketch-map of the outcrops of Greensand and Gault.



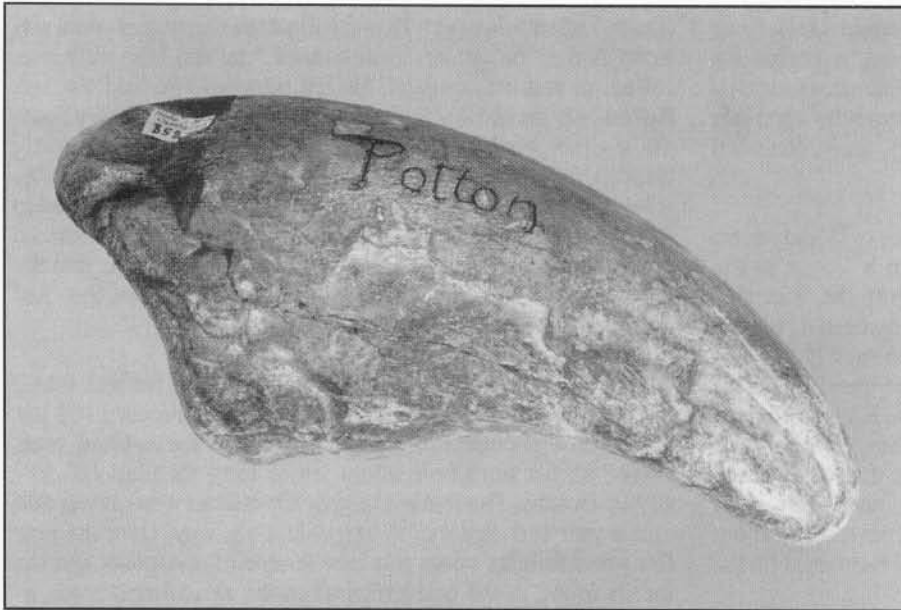


Plate 1 (above). *The Potton Iguanodon's claw (Sedgwick Museum, Cambridge).*

Plate 2 (below). *Coprolites from Sandy, Cambs. (Sedgwick Museum, Cambridge).*

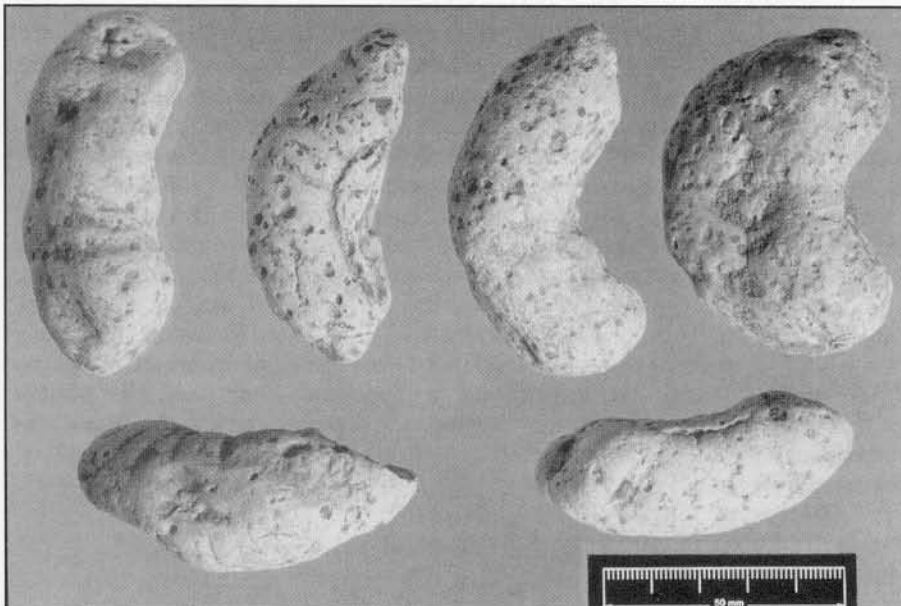


Plate 3. *Coprolites from the Red Crag of Suffolk (Sedgwick Museum, Cambridge).*



NOTES ON THE GEOLOGY (partly by T.D. Ford)

Students and professors at Cambridge University's newly established Geology department became very interested in the range of fossils being thrown up. There was extensive debate in geological circles and, over the coming decades, many argued that the deposit ought not to be termed coprolite. They should more correctly be termed pseudo-coprolites, false-coprolites or phosphatic nodules. However, the trade name "coprolite" stuck. Recently, however, an excellent example of some poor creature's rectal content has been found in Barrington that gives credence to some of the locals' views. One can make out the pressure creases and a sharp point as if it was its last squeeze!

The phosphatic nodule beds occurred at several horizons in the Cretaceous rocks of south-central England, along a belt at the foot of the Chalk escarpment stretching from Buckinghamshire, Oxfordshire, Hertfordshire, and Bedfordshire into Cambridge-shire. This belt of country was rarely more than 5 miles (8 km) wide. The nodule beds were located by ploughing turning up the occasional nodule and by trial pitting later.

Each of the coprolite beds represents a period of winnowing by strong currents on the shallow sea floor which was uplifted above wave base from time to time. The nodules were derived from underlying clay formations and concentrated by wave action. The various Cretaceous Formations were thin, often no more than 10 metres, and the nodule beds were usually less than a metre thick at the base of each unit.

Horizons with phosphatic nodules include the base of the Woburn Sands (Lower Greensand) around Great and Little Brickhill, Bucks; Ridgmont and Potton, Beds; the so-called Junction Beds at the base of the Gault near Leighton Buzzard; the Shenley Hill limestone (a calcite-cemented nodule bed overlying the Silver Sands) east of Leighton Buzzard; the base of the Upper Gault at several localities between Thame, Oxon. and Slapton, Bucks; the Cambridge Greensand, close to the base of the Glauconitic or Chalk Marl along a tract 50 miles (80 km) long from Harlington, East Beds. to Soham, Cambs. (southeast of Ely). Coprolites were also obtained from equivalent strata at West Dereham and Crimplysham in Norfolk and at Speeton on the east coast

of Yorkshire.

Nodules were also worked from the base of the Pliocene Red Crag around Felixstowe in Essex, where examples can still be found in Bawdsey Cliff.

Some production was obtained around Trumpington, Cambridge, during World War I and phosphatic Chalk around Taplow and other localities in Buckinghamshire and around Grantchester near Cambridge were investigated during World Wars I and II

The nodules were blueish-black to grey, brown or buff. Bones, teeth and claws of various reptiles have been recognized, including *Craterosaurus*, *Dakosaurus*, *Dinotocaurus*, *Megalosaurus*, *Iguanodon* and pterodactyls. Marine reptiles included *Ichthyosaurus*, *Plesiosaurus* and *Pliosaurus*. Other fossils included whales, sharks, crocodiles and turtles and a wide variety of shells, particularly ammonites. Bones and shells acted as nuclei and were encrusted with phosphatic material. Although the enclosing strata were Cretaceous in age, many of the reptile bones were derived from underlying Jurassic beds such as the Kimmeridge Clay. Thus *Megalosaurus* (Jurassic) could be found alongside *Iguanodon* (Cretaceous). The reptile fossils indicate a period when Britain was much closer to the Equator than now and enjoyed a sub-tropical climate.

Some of the phosphate was in elongate nodules with spiral markings: these are reptile droppings and hence true coprolites. The bones etc are strictly pseudo-coprolites. Other nodules were shapeless with no indication of their origin. Phosphate coatings also covered hard-grounds, i.e. strata temporarily exposed during uplift, and infilled burrows therein.

The phosphate content was usually expressed as a percentage of P_2O_5 , and ranged round 14-70%. This was the content of the nodules, not the bulk rock excavated.

The Victorian fossil hunters also recorded numerous Pleistocene mammal bones, which presumably came from interglacial and fluvioglacial deposits overlying the Cretaceous strata. The mammals included hippo, rhino, lion, hyena, bear, deer, pig, horse and oxen. Mastodon and tapir were also recorded but as these died out in Britain in early Pleistocene times, they probably came from the Red Crag. The Crag also included bones winnowed out from the Eocene London Clay. Armadillo was also recorded but as this is a South American mammal it must be regarded with suspicion. These mammal bones are not really coprolites, but doubtless added to the phosphate content when ground up and calcined.

Good specimens of both reptile and mammal bones were set aside as they could be sold to fossil collectors at high prices. Both Professor Henslow and his student Charles Darwin were among the clients. Many Victorian drawing rooms had specimens in glass cabinets and

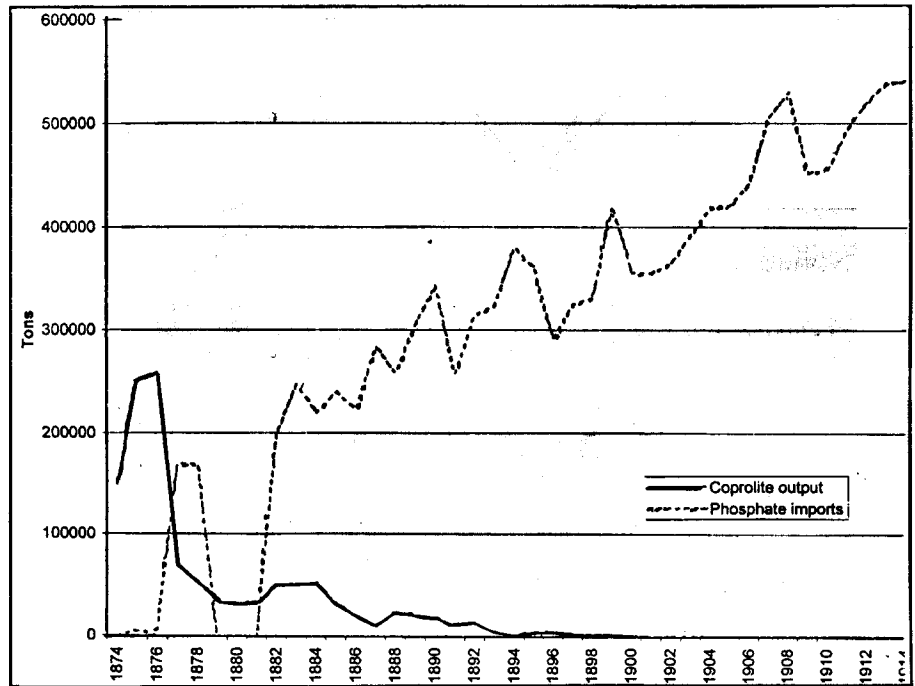


Fig. 2. Coprolite production and phosphate imports 1874-1914.

others were eagerly bought by museum curators. Some of the best examples are in the Sedgwick Museum at Cambridge.

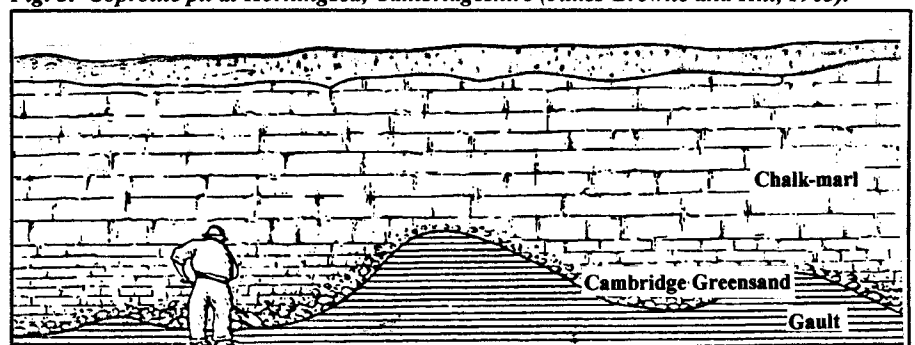
The mechanism of formation of the phosphate nodules is not fully understood but it seems likely that the inherent phosphate in bones etc was a catalyst in attracting more phosphate from sea water and concentrating it as impure calcium phosphate.

It was hardly a coincidence that the geological mapping of the country started around this time. Whilst the exploration was mainly for scientific reasons, knowledge of the extent and distribution of the Greensand was of commercial importance to those who had money to invest in the coprolite or fossil diggings. By the late-1850s pits were opened in north Hertfordshire and in the 1860s and 70s the diggings had extended into the adjacent counties with Greensand.

EXCAVATION AND PRODUCTION

The depth and extent of each coprolite nodule bed had to be determined. This was done initially by digging a coffin-like pit. A cheaper method was by using a two-man corkscrew borer. The seam was found to average about thirty inches (about 75cm.) thick but in places was up to six feet (1.8 metres) in. In some areas it was non-existent, locally called "dead land." This was due to a slight rise in the seabed whilst the fossils had tended to accumulate in the hollows. Yields therefore varied. In

Fig. 3. Coprolite pit at Horningsea, Cambridgeshire (Jukes-Browne and Hill, 1903).



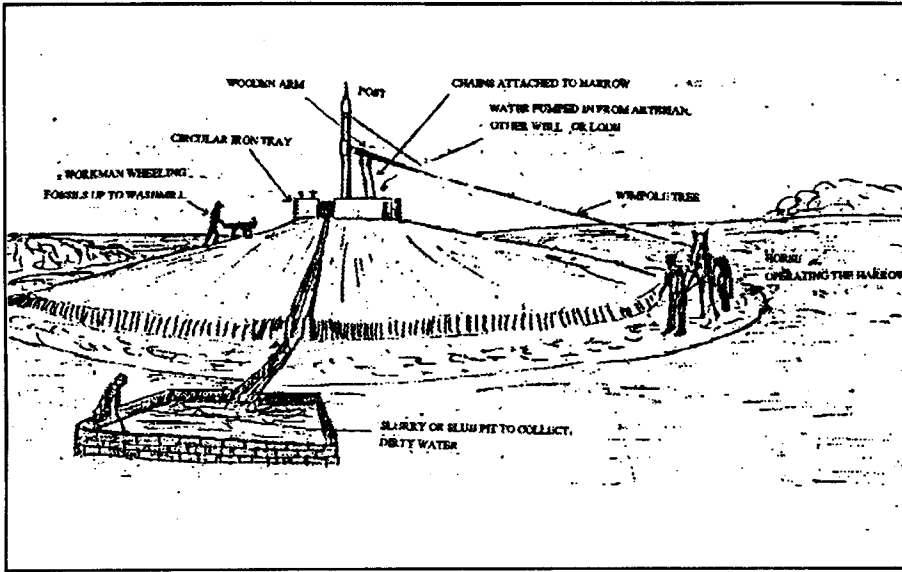
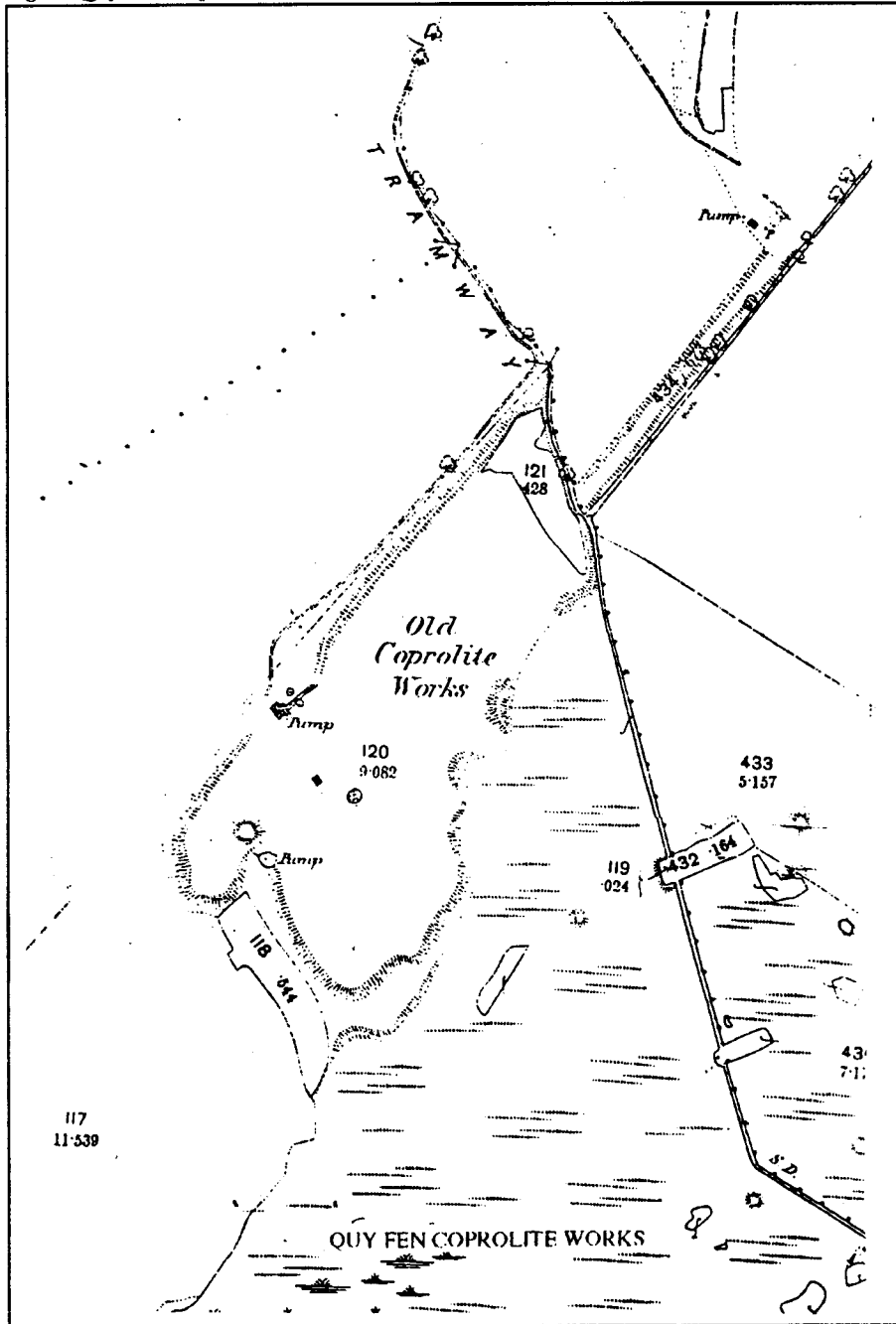


Fig. 4. Horse-powered washmill (after Grove, 1976).

Fig. 5. Quy Fen Coprolite Works, about 3 miles ENE of Cambridge (OS 25 inch 1888).



Cambridge itself it was about 300 tons per acre (0.404ha.). In one pit in Wicken it was 2,000 tons but the average was 250 tons per acre. When annual agricultural rents were rarely over forty shillings (£2.00) an acre and coprolites could be sold in the 1860s and 70s at over £2.50 per ton, potentially several hundred pounds could be made from one acre! Wages of agricultural labourers at that time would not have been over £25 in a year and £200 could have bought a (very) small estate. No wonder there was a lot of interest in them. So began what has been termed by the historian, Richard Grove, as "The Cambridgeshire Coprolite Mining Rush."

In places the nodule beds were found outcropping on the surface but in most cases they had to be dug from beneath ten and twenty feet (3-6 metres) of Greensand, Gault Clay or Chalk Marl. Where a nodule bed was found on a small property it was a simple matter for the landowner to take on a gang of labourers and have the nodules excavated. This entailed removing any bushes, trees or other obstacles. No evidence has been found of people being evicted and housing demolished so that the land beneath could be dug.

If the land was copyhold then the tenant might get permission to raise it using their labourers but occasionally, where a large-scale operation was envisaged, an advertisement might be placed in the local press and tenders invited for a contractor to do the work. This occasionally led to existing tenants being given notice to quit to allow the coprolite manager a house to live in whilst the works were in operation. More often than not, farmers were compensated for the loss of revenue from those fields which were being dug. Farmers and other entrepreneurs set themselves up as coprolite contractors and took on a gang of men and boys. Pick axes, crowbars, shovels, planks, dog irons (supports for the planks), wheelbarrows, trucks and tramways had to be bought and a horse or steam-operated washmill had to be erected to clean the soil, sand or clay from the fossils. Explosives were occasionally used in some pits to break up the fossil bed. Sheds were erected for housing plant and machinery, storing tools, sorting the fossils, having lunch or sheltering from the rain. All this cost money and local bank managers were keen to make loans to enterprising individuals in an industry that had such high returns.

VALUATION AND LABOUR

Initially the coprolite contractors agreed to do the work over a set number of years, paying the landowner a royalty of so much per ton. This entailed having a weighbridge set up by the works and for accurate measurements to be recorded. To avoid errors and dependence on the contractors' weighings, in the 1860s the land agents successfully introduced an alternative scheme whereby royalties should be paid according to how many acres were dug over the year. This entailed having the pits surveyed around Lady Day (May 1st) and Michaelmas (September 29th). The surveyor's measurements could then be used to determine how much the contractor owed. This provided local companies like Bidwell, Francis, Smith, Carter Jonas and Mann and Raven a valuable additional source of income for the next forty years. Royalties ranged from as high as £400 to as low as £30 an acre.

The average was about £100. This was about forty to fifty times the revenue the landowners could get from agricultural rents. Even after labour and other costs were deducted the contractors



Plate 4. Coprolite pit at Orwell, Cambridgeshire, c.1860-70s (Cambridge Folk Museum).

could make a big profit.

The tenant farmer was often compensated for the loss of

Plate 5. A coprolite pit in Buckinghamshire (Buckinghamshire County Museum).

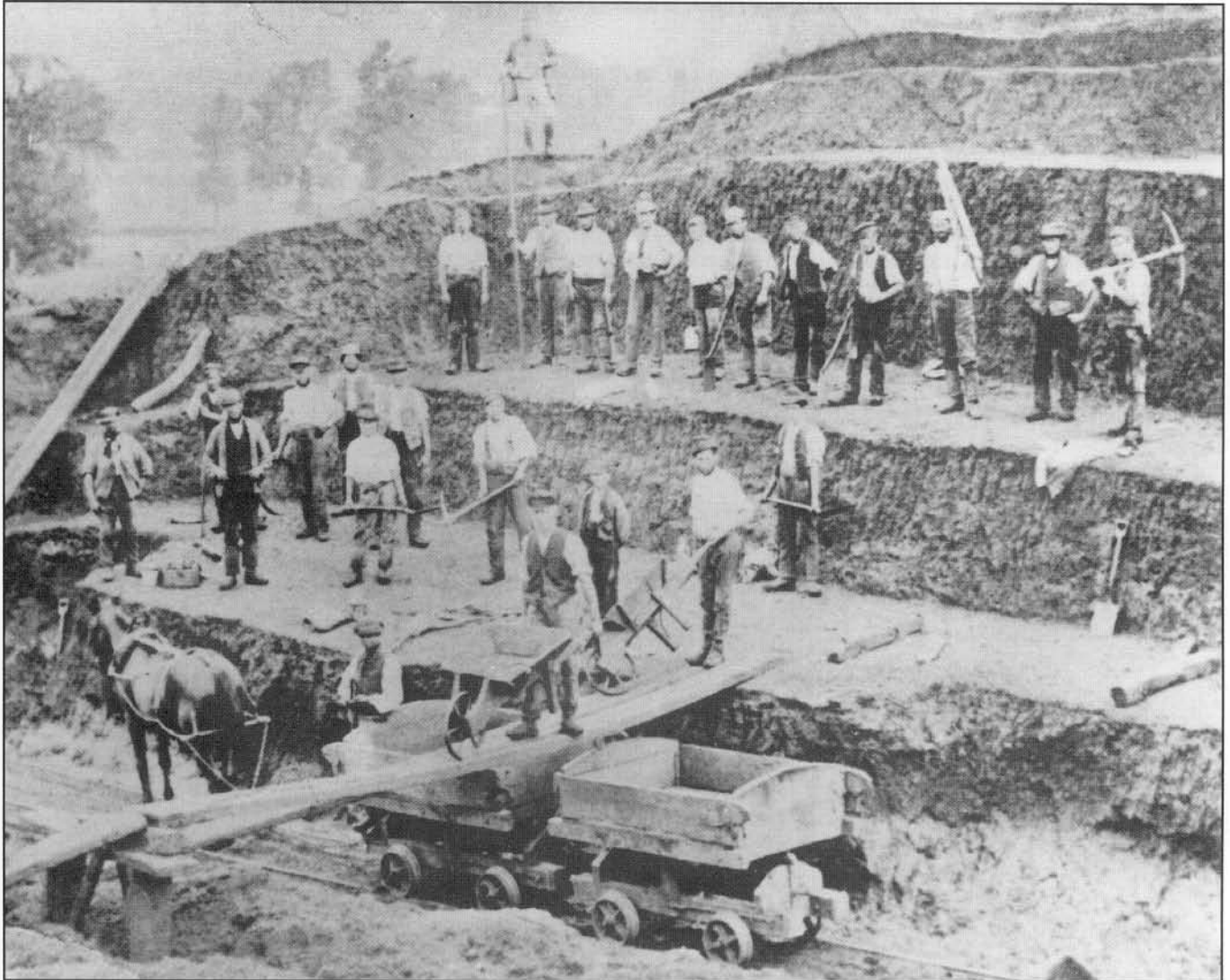




Plate 6. Coprolite digging in Cow Pasture, Abington, Pigotts, Cambridgeshire, 1883. (Photo by permission of Mr. and Mrs Schlater).

revenue from those fields out of cultivation by up to £10 an acre. The work was generally done by the farmer's own agricultural labourers during the low season, once the harvest was in. The work continued over the winter months and then the pits would be left to allow the farm work to start in spring.

However, sometimes contractors brought in a gang of outside labourers. This brought a range of social and economic problems for many parishes. The higher wages brought localised

inflation. Clothes, boots, food and drink were the main purchases but accommodation was also needed. Some rented rooms but others slept in tents, mobile barracks, farmers' barns and even on tables in local pubs and beerhouses. The brewers, aware of the demand, opened numerous beerhouses across the coprolite belt. The men were mostly in their teens and early twenties but boys as young as eight and men in their sixties were employed. There were some women and girls employed in areas where a lot of unwanted stones and pebbles needed removing

Plate 7. Steam locomotive pulling coprolite wagons from Walden to Meldreth Station, Cambridgeshire (Courtesy of Mrs Coningsby).

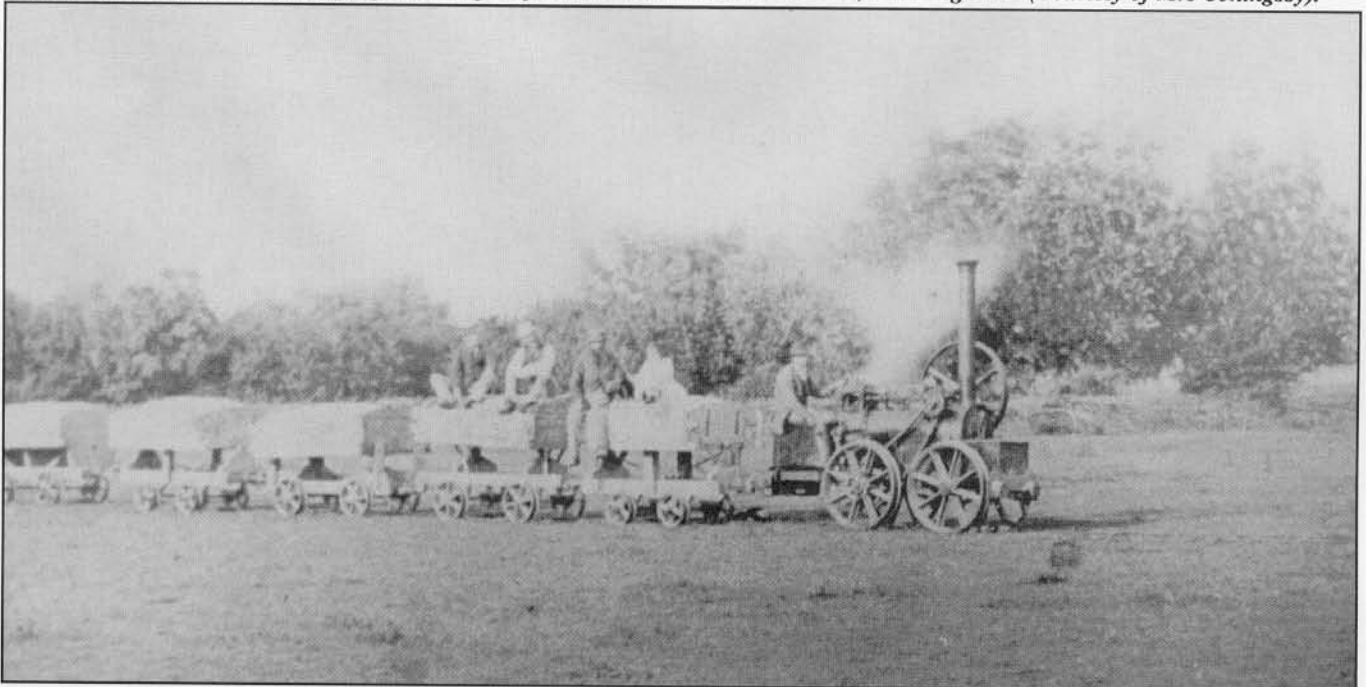




Plate 8. Tumbrils carrying coprolite to Millbrook Station, Bedfordshire (Author's Coll.).

from the washed coprolites. In Shillington in Bedfordshire 1,400 people were reported as working in the diggings.

PHILANTHROPY

The Cambridge University and District Coprolite Visiting Societies were set up to evangelise amongst the diggers. Coffee-houses and reading rooms were opened. Talks with magic lantern slides were given by visiting speakers. Treats like meat teas, suppers and evening meals were supplied. Most of these were held in the pubs. These mostly philanthropic activities met with varying degrees of success, as there were many reports in the press of drunkenness, theft, rape and assault.

Blacksmiths, carpenters, carters, iron founders, engineers, brewers and others benefited from the diggings. Some landowners were reported to make £5,000 a year from coprolite royalties. Land and property was bought; houses, farms, churches, schools and other buildings were constructed or renovated. There was a huge boost to the local economy.

Plate 9. World War I coprolite digging at Trumpington (Cambridgeshire Libraries).



WORKING PRACTICE

Once work got started the topsoil and subsoil was barrowed to one side of the field to be replaced later. In many cases it was used as the base of the washmill. As the coprolite seam was exposed the diggers shovelled it into wheelbarrows or emptied it into trucks. These were then pushed by hand or pulled by horses along a tramway that ran out of the pit, along the edge of the field or trackway to the washmill. Here their contents were unloaded to create large piles before they were washed and sorted. The soil above the seam on the new face was removed after undercutting, a process which caused considerable danger. Crowbars, pick-axes and shovels were used to make it collapse and, for convenience, it was just thrown into the trench already worked. There were numerous cases of accidents in the pits caused by collapses. This "backfilling" meant that the labourers gradually progressed across the field and onto adjoining property where a new lease was sought. Sometimes pits were opened at opposite ends of the field and two gangs of diggers gradually dug their way towards each other.

Many diggers started in their youth on

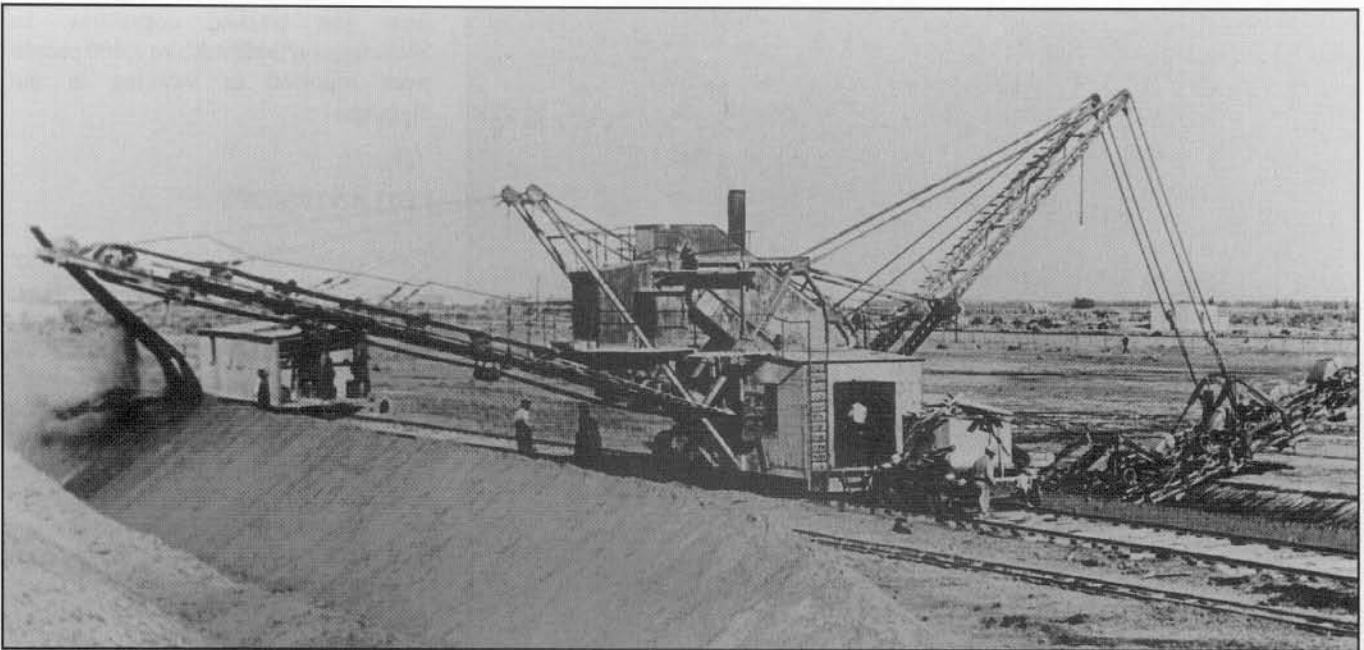


Plate 10. Mechanised coprolite production at Trumpington during World War I. (Cambridgeshire Libraries).

basic digging work and, in time, progressed through other aspects of the work. A great deal of heavy labour was involved in digging trenches to reach the seam, but occasionally the fossils were scattered within the subsoil which necessitated additional work. William Sale remembered when he was

... transferred to the job of sifting and carrying away the earth removed by the diggers. It was customary to have young lads working at the bottom of the trenches in order to handle this work, part of which involved loading and carrying a three stone tin of fossils up the planks to the pit top for removal to the washing mill. He was twelve, and his wages had been increased to the munificent sum of 5/- per week...

The boys worked in pairs, one pair to a digger and they were kept very busy. Their day started at 8am and they finished for the evening at 6pm. They were allowed half an hour for lunch and worked a six-day-week. Referring to those times as "the good old days," he said that had he been working on the land, his average wage would have been 2/- per day. When one realises that at that time the national average wage for adult men engaged in agriculture was 8/- to 10/- per week, it is little wonder that the local men preferred the pits!

On wet days, the boys practised walking the planks, imitating the skilled barrow runners and preparing for the time when, as adults, they would take their place as runners. The less experienced men usually started working at the bottom 'kench', where there was little fear of falling from the planks when the soil was being shifted. As the men gained more experience they were promoted to higher 'kenches', where the work was obviously more risky. The layers of coprolite were dug out by shovel or crowbar and care had to be taken to watch the sides of the

trenches for cracks. Collapses were fairly frequent and sometimes men became trapped beneath fallen earth. Customarily a man stood above the trench watching the sides, to shout a warning to those below at any sign of trouble. Depth of the pits varied from as little as 12 ft, but 20 ft was considered about the normal depth for both economics and safety.

Mr. Sale told of the horse-play that used to go on among the more experienced diggers, to the consternation of those below:

Plate 11. Hand-loading coprolite at Trumpington, World War I. (Cambridgeshire Libraries).



QUY FEN COPROLITE WORKS.

Rules to be observed by the workers and to be signed by each one on his entering upon his engagement with the Committee named in the Licence from Mrs. Francis.

1. Each worker shall be engaged from week to week—the week commencing on Monday morning. Any worker who may be taken on in the middle of the week shall recommence his engagement as from the following Monday morning.
2. The workers shall be engaged on behalf of the Committee by their foreman or manager for the time being.
3. Each worker shall work diligently, and under the directions and to the satisfaction of the foreman.
4. Except on Saturdays the working hours shall be from 6.30 a.m. to 4.30 p.m., from the 1st of March to the end of September, and from 7 a.m. to 4.30 p.m. from the 1st of October to the end of February. On Saturdays the work shall commence at 6.30 a.m. or 7 a.m., according to the time of year, but shall always close at 1 p.m.
5. The work is to be paid for by the yard, pitmen to receive 2 $\frac{1}{2}$ d. per yard, and second soilers 3d. per yard.
6. The pitmen shall carry their work down 4 feet wide, and shall not throw stones before or after the regular working hours, unless expressly authorised by the foreman so to do. Any pitman transgressing this rule shall forfeit his hag.
7. The second soilers shall keep their work well back. Any second soiler transgressing this rule shall for the first offence forfeit his hag, and for the second offence shall be liable to be reported to the Committee.
8. No worker shall enter the engine shed, unless expressly authorised by the foreman, or unless he have some special business.
9. The foreman is authorised by the Committee summarily to dismiss any worker introducing dog or gun upon the works, or found in pursuit of game upon the land in the neighbourhood of the works.
10. The foreman is authorised also to dismiss summarily any worker who shall maliciously damage barrows or other plant, and such worker shall be liable to prosecution by the Committee.
11. The foreman is authorised to suspend for any period not exceeding one week any worker who shall neglect his work, or who shall disobey these rules or the directions of the foreman, or who shall be drunk upon the works, or who shall be quarrelsome or riotous, or who shall use oaths or bad language to the annoyance of others, or who shall illtreat a horse, or who shall otherwise misconduct himself. Any worker who shall be suspended by the foreman, shall be liable to be reported to the Committee and, if suspended for the second time, shall in any case be reported to the Committee.
12. Any worker who shall be reported to the Committee shall be liable to instant dismissal, and shall be entitled only to the wages which he shall have earned up to the time of his suspension by the foreman.

I hereby engage with the Committee upon these terms and I undertake to observe the rules above set forth.

Fig. 6. Works rules at Quy Fen coprolite works (Cambridgeshire County Record Office R89/40).

I was told of men who actually stood on their heads on the uppermost planks and of one man who actually used to cartwheel along the length of the top plank. Mr. Street couldn't remember any incidence of a barrow falling off (Kilm 1969 pp.40-41).

Two other methods of mining were recorded. In the early-1860s a storm exposed the bed in the cliffs at Speeton, North Yorkshire. It was reported that (Judd 1868 p250)

... timbered adits are driven into the cliff at points below the outcrop of the cement bed ... (where they meet the bed) galleries are driven in every direction in the bed itself, the material and refuse being carried out in small wagons running on tramways which are laid down in the adits. The stone is usually conveyed by train to Hull by railway.

As the Speeton nodule bed only averaged 5 inches in thickness, it was too expensive and soon abandoned. However, about 500 tons were exported each year with a phosphate content of 57 - 61%. Whether this operation stimulated the more conventional mining method in Cambridgeshire or *vice-versa* is uncertain.

At Bassingbourn, near Royston, Beds. it was reported (*Cambridge Chronicle*, 10th February, 1866 p.5)

BASSINGBOURN. New System of Works. - A new system of works has just been introduced into this county for the recovery of fossils or coprolites from the deep beds of the earth by Mr. C. Cooper of Bassingbourn. The principle is that used in mining operations, a shaft being sunk to considerable depth, and headings formed to run diagonally to the main shaft by tramways so that an immense amount of labour is saved by bringing the stone up by steam power. The engines are fitted by Mr. Cooper on the most modern and approved plans, and are well adapted for the purpose.

For how long this operation lasted is unknown but later geological reports show that the thin seams and the problems of underground water persuaded Cooper to return to open cast mining. A local farmer remembered as a young lad playing in the waterlogged entrance of a mine with its wooden supports. Further evidence of the mine came when the laying of the gas pipeline across the 11-acre field of Home Farm uncovered it a few feet below the surface. It had been dug out of the Gault Clay and was about three feet wide and six feet high with, unusually, a gabled roof. It was explored for a number of metres in a dogleg but deep water precluded a further search. These sites have apparently been filled in but the tunnel still exists beneath the area.

Numerous accidents were reported at the coprolite works. There were cases of people drowning in water-filled pits. Double ruptures were common. People got run over by coprolite trucks or steam engines, were injured or killed by falling dog irons and got their clothes caught in machinery and had limbs twisted or torn off. Many had limbs crushed or were buried in unexpected collapses. Although contractors were encouraged to employ "watchers" at the top of the pits there was no evidence they did.

WASHING

The job of washing the fossils got progressively easier over the years. Initially the technique in Suffolk was to dig a trench into the side of the estuary or the river (Tye 1930 p3-4):

The coprolites, along with a certain amount of dirt and bones, were shovelled into sieves which, when full, were placed on a ledge in the tank, just under the surface of the water; to each sieve was fastened a long pole, which the washer pulled backwards and forwards until the stones were clean. When there was a shortage of water, in or near the pit, the washing was done at the quayside before loading.

In other parts of the country without access to a tidal estuary, innovative engineers used their skills to develop sophisticated washmills powered by horse or steam engine. A mound was constructed using the top and subsoil. On top of this mound a circular brick base was laid onto which a circular iron tray was placed. A pump was often installed to bring the huge quantities of water needed from a nearby water source. Wells sometimes had to be dug and lined with bricks. The cost of constructing these mills in the late-1840s when they were first developed was £100 but by 1875 the "coprolite contractors had become so expeditious that a hill could be put up for £50"

Fig. 7. Sale notice of coprolite plant at Bassingbourn, 1870, (Cambridgeshire County Record Office, 296/B9.17).

BASSINGBOURN,
CAMBS.

A CATALOGUE OF
AN IMPORTANT SALE OF
SECOND-HAND
COPROLITE PLANT
AND
FARM MACHINERY,
INCLUDING
4 PORTABLE STEAM ENGINES,
2 Vertical Boilers with Hoisting Engines, 2 Threshing Drums
& Horse-power Threshing Machine, Reaping Machine,
Weighing Machine, Double-action Hand Pump, 2 Water Carts, Screening
Machines, Turn Tables, Water Tank, a large quantity of Wheels, Pulleys and
useful Iron; Posts and Timber, and various Effects;
WHICH

MESSRS. NASH & SON

Are instructed by W. P. Colchester, Esq., to hold
On Thursday, the 23rd of June, 1870,
At 12 for 1 o'clock,
At his Factory in the High Street.

May be Viewed the day prior to and on Morning of Sale.

Catalogues may be had on the Premises; and of the Auctioneers, at Royston.

ROYSTON PRESS: JOHN WARREN.

As the technology improved, steam powered washmills were introduced. Some were like a vertical waterwheel, others like a vegetable washer. After several washings the dirty water, locally termed "slub" or "slurry," was run back into "slurry pans" to dry out before the topsoil was replaced. In some cases it was run back into the coprolite pit. The theory was that, once dried, the cracks in it would allow better drainage once the pit was filled in and levelled. As the work progressed across the field the mill was transferred to a more accessible site. The subsoil was shovelled onto the side of the pit where the coprolites had been dug and topsoil was barrowed back to the trench or slurry pit and the field drained and levelled ready for cultivation. Whilst the theory was that this process would improve the soil, in practice the operation was not always done thoroughly. It was cheaper for a contractor to cover it up quickly and move on. Farmers, however, would take care as they would benefit from improved cropping. In many areas white chalk markings can still be seen on the fields which indicate where slurry was not properly covered or the topsoil replaced. Astute land agents ensured that agreements included very precise instructions for this process and subsequent drainage, levelling and seeding.

Horses would have been a common sight hauling tumbrils, wide-topped, wooden carts, loaded with washed coprolites along the farmtracks and roads to the mill, wharf or railway sidings at the nearest station. The return journey was often with quantities of stable manure from London and other big cities that was taken back for the fields.

MARKETING

With "superphosphate" being sold at up to £7 a ton, half the price of guano, it became much in demand across the country. It was not long therefore before sales were being promoted across Europe, in America and throughout the Empire. There were reports of sales as far afield as Russia and Queensland. During the 1860s a new chemical manure works was set up on Burwell Lode near Burwell, near Newmarket. As well as three in Cambridge there were four on the Cambridge to Hitchin railway line at Duxford, Shepreth, Royston, Odsey, near Ashwell and another on the main road from Wimpole to Bassingbourn. Many corn mills had to be converted to grind the coprolites as the gritstone was not hard enough. A hard buhrstone had to be installed in its place.

Suffolk and Bedfordshire coprolites did not fetch as high a price as those in Cambridgeshire. In 1856 manure manufacturers were paying an average forty-three shillings and sixpence (£2.18) a ton for Cambridge coprolites. By 1874 it was just over sixty-one shillings (3.05). With yields averaging 250 tons an acre one can understand why the deposit had been extensively mapped by the 1870s. Although the Upper and Lower Greensand beds were not continuous, there is documentation showing the fossils at their base were worked in parts of Norfolk, Cambridgeshire, Hertfordshire, Bedfordshire, Buckinghamshire, Oxfordshire, Hampshire, Yorkshire and Kent. Its enormous extent allowed many new manure companies to capitalise on this new raw material and take a share of the increasing market for artificial fertilisers.

The boom year was 1876 when production peaked at

POOR'S FEN, QUY,
C.A.M.B.S.

CATALOGUE OF ALL THE VALUABLE

COPROLITE PLANT

COMPRISING

About 20 tons of Tramway Rails, 40 Barrows, 10 Trucks,
70 Planks, 60 long Slurry Troughs, 40 Hoisting Frames,
25 Crow-bars, 10 large Tubs, and Tanks, Washing Mill
and Slurry Wheel, complete,

2. WELL-BUILT ENGINE HOUSES,
2 TIMBER-BUILT STABLES,
LARGE MESS ROOM,
AND
5 in. and 7 in. Centrifugal Pumps,
CAPITAL 10-H.P. PORTABLE ENGINE,
Quantity of Cast-iron Piping, 6 Driving Straps, and
numerous other Effects.

WHICH MESSRS.

WRIGHT AND SCRUBY

Are instructed to sell by Auction, upon the Works, close to
Quy Station, G.E.R.

ON TUESDAY, OCTOBER 30th, 1894,
At Eleven o'clock in the Morning.

Catalogues may be obtained of the Auctioneers, Cambridge
and March.

J. Webb & Co., Printers, Alexandra Street, Cambridge.

Fig. 8. Sale notice of Poor's Fen, Quy, coprolite plant, 1894.
(Cambridgeshire County Record Office, R89/40).

258,150 tons a year. However, with the exhaustion of the guano deposits four years earlier, demand for phosphates led to exploration overseas. Increasing quantities were imported from Spain, Canada and more particularly from Charleston, South Carolina.

Four successive years of heavy rain at the end of the 1870s caused problems for farmers. Yields dropped and many went out of business. The then Tory government introduced the Free Trade Act which allowed cheap imports of meat and grain from the American prairies and Argentinean pampas. As a result demand for superphosphate fell which in turn affected the coprolite industry. Coprolite prices fell from a maximum £3.72 a ton at their peak to less than £1.50. Although the industry did not cease completely, production plummeted to 30,500 in 1880. Many contractors went bankrupt and coprolite pits were abandoned.

There was a revival in the 1880s and 90s occasioned partly by demand from inland manure companies who had to pay high freight costs to bring in the foreign phosphates but also because their directors and shareholders often included coprolite contractors, merchants and farmers who still had coprolite reserves. However, the gradual exhaustion of the shallow seams,

increases in the price of coal and freight charges on the railways led to the industry becoming increasingly unremunerative. The 1894 Quarries Act introduced strict health and safety regulations for pits over twenty-five feet deep which effectively signed the death knell for the remaining diggings. Although some pits kept going until the turn of the century, production had dropped to 620 tons in 1900.

During the First World War there was a brief revival. The Ministry of Munitions, concerned about the reduction of phosphate imports caused by German naval attacks on the merchant fleet, set up a large-scale operation in Trumpington and Grantchester, just outside Cambridge. Three thousand men were reported as involved, many of them Irish prisoners-of-war after the 1916 uprising. The technology involved was far superior to anything seen in the 19th century but before one ton of coprolite left the site the Armistice was signed.

Thousands of acres were worked which revealed extensive evidence of archaeological interest. Today there is little evidence of the diggings. Tramways and machinery was sold or buried in the pits. Some fields are a few feet lower than the adjoining ones. Long, narrow ponds are abandoned pits and bare patches in the fields are often the sites of slurry being run onto the surface or not being covered with topsoil. This unusual industry brought hundreds of parishes a level of prosperity never experienced before.

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Website: - www.coprolite.care4free.net/index2.html

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