CANADA

DEPARTMENT OF MINES

HON. W. A. GORDON, MINISTER — CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN McLEISH, DIRECTOR

A Study of Clay Winning and Its Costs in the Provinces of Ontario and Quebec

BY

J. F. McMahon

OTTAWA
J. O. PATENAUDE, I.S.O.,
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1935

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A Study of Clay Winning in Ontario and Quebec

CHAPTER I

INTRODUCTORY

Millions of tons of clays and shales are won yearly for the production of brick, tile, sewer pipe, drain tile, firebrick, chinaware, wall and floor tile, cement, and a host of other products that are made from these raw materials. The winning of these materials is not usually an industry in itself but rather a step in the manufacture of clay products. The producer of clay products usually owns and operates his own source of supply of raw materials. There are, however, several types of clay which, due to their particular qualities and limited distribution, are won merely for sale and not for direct utilization. Included in these classes are:

China clays or kaolins, utilized in the manufacture of whitewares and in the paper industry.

Ball clays, utilized in the whiteware industry.

Slip clays, utilized in the stoneware industry for their glazing properties and in the grinding-wheel industry for their burned bonding properties.

Suspension clays, such as are utilized in the enamelling industry, etc.

These clays present certain special problems which will not be considered to any extent in this report.[1]

The great bulk of clays and shales won go into direct production of the heavy clay products, and the winning operation is usually considered a step of manufacture and, consequently, is generally under the plant superintendent. In some cases, particularly in underground workings, an experienced foreman is in charge of the operation.

PURPOSE OF REPORT

The object of this investigation, which was commenced in 1927, was to assemble and analyse production cost figures so as to aid the clayworker in his choice of clay-winning methods and equipment, and to assist him to cut down his cost of production. The figures presented were obtained by the writer in the course of field work during the summers of 1926, 1927, and 1928.

A preliminary report (Reference 209)[2] was published in "Investigations in Ceramics and Road Materials, 1927," and a progress report (Reference 210) was published in "Investigations in Ceramics and Road Materials, 1928-29."

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[1] For information on these clays the reader is referred to the following references in the Bibliography: Ref. 9, 15, 16, 18, 34, 37, 39, 40, 42, 45, 48, 49, 50, 51, 66, 68, 88, 96, 100, 106, 107, 111, 118, 122, 133, 134, 139. 184. 188. 202. 271, 284, 287.

[2] References will be found under Bibliography, see pp. 78-87.

ACKNOWLEDGMENTS

Appreciation is expressed for the supervising assistance and kind criticisms of Howells Fréchette, Chief of the Ceramics and Road Materials Division, Mines Branch; for the capable field assistance of Edward Lester of the same division; and to the members of the Mines Branch library staff for co-operation in compiling the bibliography.

The writer extends his grateful thanks to the officials of the following companies who by their courtesy and co-operation have made the investigation possible:—

Joseph Hodder, Dutton, Ont.
Campbell & Sons, West Lorne, Ont.
Aaron Hill, Essex, Ont.
Broadwell & Son, Kingsville, Ont.
Interprovincial Brick Co., Toronto, Ont.
Toronto Brick Co., Toronto, Ont.
Milton Brick Co., Toronto Ont.
Halton Brick Co., Toronto, Ont.
Cornhill & Sons, Chatham, Ont.
Jasperson Brick & Tile Co., Coatsworth, Ont.
C. R. Gammage, Dresden, Ont.
Wm. S. Hallatt, Merlin, Ont.
A. W. Hill, Stevenson, Ont.
Ontario Denison Tile Co., Windsor, Ont.
Grimsby Brick & Tile Co., Grimsby, Ont.
F. R. Paxton, St. Catharines, Ont.
Phinn Brothers, London, Ont.
Brampton Pressed Brick Co., Brampton, Ont.
Cooksville Shale Brick Co., Cooksville, Ont.
Curtis Brothers, Peterborough, Ont.
Bartonville Pressed Brick Co., Bartonville, Ont.
Hamilton Pressed Brick Co., Hamilton, Ont.
Ollman Brothers, Hamilton, Ont.
National Fire Proofing Co., Aldershot, Ont.
Dominion Sewer Pipe Co., Swansea, Ont.
Price & Smith, Toronto, Ont.
Sun Brick Co., Todmorden, Ont.
Don Valley Brick Works, Ltd., Todmorden, Ont.
Ontario Sewer Pipe & Clay Products, Mimico, Ont.
Booth Brick & Lumber Co., New Toronto, Ont.
La Brique de Scott, Ltee., Scott Junction, Que.
Montreal Terra Cotta Co., Lakeside, Que.
National Brick Co. of Laprairie, Laprairie, Que.
St. Lawrence Brick Co., Ltd., Laprairie, Que.
La Compagnie de Briques de L'Islet, L'Islet, Que.
Citadel Brick Co., Montmagny, Que.
Frontenac Brick Co., Beauport, Que.
Granby Clay Products Co., Granby, Que.
Ascot Brick & Tile Co., Ascot Corner, Que.
Eastern Townships Brick & Tile Co., East Angus, Que.

NATURE OF NOTES TAKEN

Forty-eight plants belonging to the above-named firms were visited by the writer, but only results that are considered as having direct bearing on the subject are published, and data obtained at several plants are omitted, in accordance with the wishes of the operators. The information so obtained, however, was used in arriving at conclusions.

As the field work progressed, the more complete were the data obtained and the more illuminating were the results. The general questionnaire and record form are given below in order that they may be of service to those interested in similar investigations in the future, and also that the method of arriving at the results herewith published may be seen.

WORKINGS NO.

General Notes and Questions

1. Nature of country...Hilly.
2. Nature of material...Hard shale
3. Type of product made...Building brick.
4. Relative position of plant to workings...........................50 feet below.
5. Distance of workings from plant...............................3,000 feet.
6. What was last year's tonnage of clay?........................... ....
7. What was last year's tonnage of shale?...........................60,000
8. How many months a year?................................... 10
9. How many hours a day?................................... 10
10. Are separate clay-winning accounts kept?....................... No.
11. Does clay winning at present give rise to shutdowns?............. No.
12. Is there any provision for storage?............................. No.
13. Is there a foreman in charge of winning operations?............... Yes.
14. Is it necessary to remove overburden?........................... Yes.
15. What lies over the desired material?...........................Stony clay.
16. What lies under the desired material?...........................Shale.
17. What is the depth of the desired bed?...........................50+feet.
18. What is average daily tonnage?...........................350
19. What amount of dynamite is used in a year?.....................40 boxes.

WORKINGS NO.

Description of Deposit

Material Won—
Clay or shale.........................Shale
Weight per cubic yard................
Hardness...................Very hard
Manufactured into.......Building brick

Foreign Materials—
Stones......................... None
Strata......................... None
Amount..........................

Face—
Top soil............Stony surface clay
Depth of material won...........15 feet.
Base soil.......................Shale

Type of Working—
Surface......................... Yes
Bank......................... ..
Pit......................... Yes
Mine......................... ..

Drainage—
Mechanical...........................
Natural...............................
Importance..Troublesome if not drained

Overburden—
Depth..........................4 feet
Nature..............Stony surface clay
Removal...By power shovel twice a year

Distance from plant............3,000 feet

Output—
Tons per day { raw material............ / product.................
Yards per day........................
Brick per day....................80,000
No. months operation per year...... 10
No. hours operation per day........ 10

WORKINGS NO.

Labour

—	No.	Rate
		$
Driller	1	0·40 per hour
Driller helper	1	0·35 "
Craneman	......	....
Engineer	1	5·00 per day
Fireman	..	....
Horse driver	1	3·00 per day
Watchman	..	....
Drum operator	1	0·40 per hour
Locomotive operator	1	0·45 "
General labour	2	0·35 "

WORKINGS NO.

General Equipment

—	Pumps	Motors	Sump	Wire	Pipe
Number	1	1	None	....	....
Type	Centrifugal	D.C.	....	....	....
Make	....	....	....	....	....
Cost	$150	$250	....	$100	$100
Yearly repairs	$ 10	$ 25	....	$ 20	$ 20
Age	6 years	3 years	....	3 years	6 years
Feet	....	....	....	500	1,000
Oil per day	....	....	....	....	....
Gasoline per day	....	....	....	....	....
Electricity per day	....	90 kw. hr.	....	....	....
Horse-power	....	50	....	....	....
Efficiency	Satisfactory	Satisfactory	....	....	....

WORKINGS NO.

Drilling and Blasting Equipment

	Number	Type	Cost	Yearly repairs	Age, years	Feet	Oil per day	Gasoline per day	Electricity per day	H.P.
			$	$					kw. hr.	
Motors	None									
Drills	2	Air	200	100	3					
Compressor	1		150	175	3				3	
Wiring										
Piping			100	25	3	1000				
Bits	20	Star	100		1					
Picks	1		2	Used up						
Shovels	1		2	Used up						

WORKINGS NO.

Digging Equipment

	Number	Type	Make	Cost	Yearly repairs	Age, years	Feet	Oil per day	Gasoline per day	Electricity per day	Coal per day	Bucket	H.P.
				$	$					kw. hr.			
Power shovel	1	Elec.		2,500	250	3		1 qt.		90		½ yd	
Ditcher													
Planer													
Scraper													
Dragline													
Plough													
Harrow													
Cable													
Hand tools	12	Shovels		24	Used up								
Piping													
Wiring				250	25	3	1,000						
Tractor													

WORKINGS NO.

Hauling Equipment

—	Number	Type	Make	Cost	Yearly repairs	Age, years	Feet	Oil per day	Gasoline per day	Electricity per day	Coal per day	H.P.
				$	$					kw. hr.		
Rail	....	20-lb.	..	1,000	100	3	6,000	....	....	......	....	..
Ties	200	....	..	100	25	3	......	....	....	......	....	..
Cars	10	Steel	..	800	80	3	......	....	....	......	....	..
Trucks	....	....	..	......	....	..	......	....	....	......	....	..
Wagons	....	....	..	......	....	..	......	....	....	......	....	..
Carts	....	....	..	......	....	..	......	....	....	......	....	..
Cables	....	....	..	150	50	1	300	....	....	......	....	..
Drums	1	18-in.	..	150	20	4	......	....	....	3	....	..
Motors	....	....	..	......	....	..	......	....	....	......	....	..
Trestles	2	....	..	300	30	6	......	....	....	......	....	..
Towers	....	....	..	......	....	..	......	....	....	......	....	..
Posts	....	....	..	......	....	..	......	....	....	......	....	..
Horses	....	....	..	......	....	..	......	....	....	......	....	..

WORKINGS NO.

Material Used

—	Amount	Rate	Charge to
		$	
Oil	1 quart	0·50	Digging
Gasoline	....	....	....
Natural gas	....	....	....
Electricity	96 kw. hr.	0·04 per kw. hr.	Drilling, digging, hauling.
Coal	....	....	....
Dynamite	8 sticks	0·80	Drilling, blasting.
Caps	....	0·25	Drilling, blasting.
Straw	....	....	....
Fuses	....	....	....

Having summarized the information, the data were accumulated in a form similar to the following:—

WORKINGS NO.

Nature of country	Hilly.	Distance from plant to workings	3,000 feet.
Nature of material	Shale.	Average daily tonnage	350
		Type of product made	Stiff-mud building brick.
Depth of bed worked	15 feet.	Cost system	Good.
Overburden	4 feet.	No. of working hours per day	10
Relative elevation of plant to workings	50 feet below.	No. of months operation per year.	10
		Drainage	Good.

General Remarks

Labour and equipment	Rate per hour	Value	Yearly depreciation	Yearly interest	Yearly repairs	Rate per day	Cost per day	Cost per ton
	$	$	$	$	$	$	$	$
Engineer	......	....	....	....	....	5·00	5·00	0·03
Power shovel	......	2,500	250	175	250	......	24·00	0·16

The figures in the above table were further summarized and reported as shown in the following:—

Cost per Ton of Shale (Clay)

Supervision:		
Labour	$ 0·00	
Drilling and Blasting:		
Labour	0·02	
Equipment	0·01	
Material	0·04	
		$0·07
Digging and Handling:		
Labour	0·05	
Equipment	0·18	
Material	0·05	
		0·28
Haulage:		
Labour	0·04	
Equipment	0·07	
Material	0·02	
		0·13
General:		
Labour	0·05	
Equipment	0·04	
Material	0·02	
		0·11
Total		$ 0·59

COST STUDY

(References 64, 70, 75, 93, 94, 100, 120, 127, 141, 147, 197, 206, 241, 255, 262, 276, 282, 285)

A general study of clay-winning costs with the object of obtaining information that will lead to more economical operations is a large undertaking, and a complete analysis presents many difficulties.

Costs might be reported in any one of the following ways:

1. As *apparent costs,* as was done in this report, in which all factors are taken into consideration, certain rates of depreciation and repair being assumed, the labour and material charges being actual figures.
2. As *total actual costs* that give all details of costs, including actual figures as to interest, depreciation, insurance, overhead, besides the labour and material costs.
3. As *operating costs,* giving only the labour and material costs, without any reference to investment and factors pertaining thereto.

The actual cost of operation is of the greatest value to the operator himself, and he is the only one who can correctly compute it or arrange for its computation. It is necessarily founded on book-keeping and requires systematic attention. The futility of a general investigation in this regard is, therefore, realized and although the figures obtained would be of value to the industry—for a matter of comparison—this value is hardly worth the great amount of necessary additional study, nor is it possible to obtain for publication this type of information.

Operating costs are valuable for comparison of labour and material charges, but omission of the important items of interest, depreciation, and repairs takes away from this value. However, by combining operating costs with assumed fair rates of depreciation, repairs, and interest, it would seem that the best comparable figures are obtained, and that apparent costs afford a better picture than operating costs and are, therefore, of more general interest than actual costs.

Depreciation

A depreciation rate of 10 per cent was considered fair for most equipment, while the following rates were used for special equipment:

	Per cent
Rails	5
Machine-loaded cars, tipples, wagons, carts, harness	15
Machine-loaded shale cars, cable, animals under some conditions	20

It is felt that if the above rates are criticized, the only thing that can be fairly said is that they are too high, for the clay-product manufacturer makes his clay-winning equipment last a long time.

Repairs

For upkeep and repairs 10 per cent of the value of the equipment was considered fair, with the following exceptions:

	Per cent
Machine-loaded clay cars	15
Machine-loaded shale cars	20
Cable	20

These figures are of course not altogether accurate, as the cost of equipment has nothing to do with the cost of repairs, only in so much as replacement parts are concerned. The figure is apt to be low inasmuch as it does not take into consideration loss of time resulting from breakdowns.

Interest on Investment

Seven per cent was considered a fair rate of interest and was used except where otherwise noted. With some producers this figure is low.

BASIS FOR DETERMINING COSTS

For the purposes of this investigation the cost of delivering a ton of raw material to the mill was chosen as a basis. This basis was chosen due to the fact that it is generally accepted in the clay-working industries and because it can be easily converted to almost any other basis where desired.

In choosing such a basis for calculating the cost of winning clays the following were considered:

Cost per Thousand Brick or per Ton of Tile. Neither of these would act as a suitable basis because some plants make brick only, and others tile only, while others make both. Such being the case two bases would have to adopted.

Cost per Cubic Yard. This is used in some plants, but is not a term generally quoted in a ceramic plant. It is used in excavation work where yardage of excavation is the important factor.

Conversion Factors. For converting to other bases the following are useful:

One cubic yard of clay, dry broken = 0·85 ton.
One cubic yard broken shale = 1·14 tons.
The amount of loss in the burning of clay or shale will vary greatly from 6 per cent up.
Canadian burned brick average about six pounds in weight.
Material required for 1,000 brick is somewhat over three tons of raw material.

DIFFICULTIES MET WITH IN THIS INVESTIGATION

The difficulties met with in trying to study the costs of winning of clays and shales to promote economies were as follows:—

First. The lack of knowledge of actual costs by a large number of the operators.

Second. The desire for steady output overshadowing the desire for low costs on the part of the operators.

Third. The futility of attempting to change either the type of equipment or the manner of working.

The importance of the keeping of statistics by the operators on the clay-winning operations should not be overlooked. This is the only way by which much will be learned concerning costs of various types of operations and thereby bring about a lowering of general costs. Relative to the importance of this matter and manner of keeping records, the following references are given: 2, 22, 75, 79, 93, 94, 101, 102, 103, 104, 105, 108, 109, 114, 116, 126, 127, 135, 141, 147, 159, 166, 189, 191, 197, 204, 205, 206, 207, 214, 217, 241, 242, 245, 250, 255, 262, 268, 276, 281, 282, 285, 289.

OPINIONS OF EQUIPMENT MANUFACTURERS

The manufacturers of clay-winning equipment are only too glad to be of assistance to those interested in their machines and they can usually be depended upon to give detailed information relative to the application of their equipment and costs of operation. During the course of this investigation a number of equipment manufacturers were interviewed.

Clayworkers tend to buy second-hand equipment; their choice of locomotive varies from 4 to 10 tons in size, but the most of them demand the 4-ton size.

Locomotives can be had in any gauge, but the clay man is advised to lay tracks of standard industrial gauge, particularly 24-inch, 30-inch, or 56½-inch, in order that his equipment may be more cheaply purchased and more easily sold when he has no further use for it. For locomotive haulage the grade of tracks should not exceed 5 per cent. The most popular sizes of shovel sold to the trade are ½-, ¾-, and 1-yard. Many makers sell rebuilt machines, which they recommend to the clayworker. On an average a good rebuilt machine can be purchased for about $8,000. The manufacturer of a shovel, when a purchase is being made, is interested in two things: first the type of material to be worked, and second the desired capacity. Some manufacturers recommend, when hard digging is encountered, the placing of a small dipper on a large chassis, but other companies do not favour such an arrangement. They claim that the use of explosives is economical, as by their use the life and capacity of the shovels are increased; however, the skill of the shovel operator also has much to do with its length of life.

Steam is fast being replaced by electricity or gasoline.

DEFINITION OF TERMS USED IN THIS REPORT

Loading. The operation or operations by which the material, having been freed, is placed in a conveyance.

Transportation (Delivery). The operation or operations by which the material is delivered from its loading point to the place where it is to be processed.

Digging. An operation by which the material is removed from its bedding without the use of explosives.

Workings. The place where any kind of winning operation is carried on.

Pit. The workings in which the desired materials are obtained by surface operation.

Mine. An excavation from which a desired material is won by means of workings below the surface.

Surface Operation. An open-cut excavation.

Mining Operation. An underground working.

Winning. Digging, loading, and transporting the desired material.

Ton. The short ton of 2,000 pounds avoirdupois.

CHAPTER II

METHODS OF CLAY WINNING

FACTORS AFFECTING CHOICE OF METHOD

There are four outstanding factors which affect the methods of winning:—

1. Available capital;
2. Quantity required;
3. Geological and topographical features;
4. Relative location of plant to winning operation.

Available Capital

As in all other lines of endeavour, the capital available materially affects the winning of clays and shales; it may be ample, limited, or decidedly limited. Capital being ample permits expenditure for the highest priced types of equipment and a machine for every job for which a machine is made. In general the theory has been that machines are more economical than hand labour. Hence the tendency of the operation backed by ample capital is to become equipped with machinery to an uneconomical point of expenditure. It is perhaps the operation that is backed by a limited amount of capital that is most economically equipped. The expenditures under such limitations, while they can be made, must necessarily show their advantages in actual dollars prior to their being authorized, and, therefore, economies are practised to the utmost; most of our plants are in this class. An operator who has very little money for plant equipment finds it more advantageous to pay men by the week for their labour than to tie his money up in equipment.

Quantity Required

Some clay and shale deposits are worked the year round, whereas others are worked only in the summer months. Those in the former class afford the best opportunity for the installation of mechanical devices, the daily demand being the controlling factor as to the types. Deposits that are operated for say only four months in the year cannot always utilize economically the class of equipment used in those having a more lengthy working period, as it is not profitable to carry heavy equipment charges for the short working periods involved.

Geological and Topographical Features

(References 25, 67, 71, 95, 97, 123, 173, 179, 192, 194, 232, 238, 247)

The geological and topographical features of the deposit affect the mode of operation inasmuch as they concern the hardness of the materials handled, the amount and nature of the overburden, the presence and distribution of undesirable materials, the depth of the beds, the conformation of the country, etc. The methods used in the extraction of a hard shale might in some cases be applicable to the extraction of softer materials but the expenditure would be unduly high; conversely the most economical procedure for the winning of soft material would be useless on hard shales. Stripping methods on a 3-foot overburden (*See* Workings No. 18) are not applicable to the removal of a 10-foot overburden (*See* Workings No. 32); a 6-foot face of clean material (*See* Workings No. 19) cannot be most economically worked in the same fashion as the same height of face containing undesirable materials (*See* Workings No. 24), nor is it wise to operate a 6- to 16-foot bed of material (*See* Workings No. 37) in the same fashion as one that is from 50 to 75 feet in thickness, (*See* Workings No. 47). The geological features of the deposit affect not so much the amount of equipment as they do the type.

Relative Location of Plant to Winning Operation

While the capital available, output required, and geological and topographical features affect to some extent the delivery of the material, the important factor in this consideration is the relative location of plant to winning operation. They may be distant from each other (*See* Workings No. 20), or may adjoin (*See* Workings No. 18); they may be on the same or on different levels. They may be separated by intervening hills, valleys, swamps, roadways, or railroads, all of which affect the choice of delivery equipment.

Clay and shale beds, with few exceptions, are worked as surface or underground workings. One operation in New Jersey is worked from under water by dredging (Reference 263) but the only reason for such a type of operation is scarcity of material.

SURFACE WORKINGS

While underground mining operations can be standardized to some extent, the conditions met with in surface operations are so diverse that it is difficult to discuss them in a simple fashion. Classification of surface workings might be made according to the nature of the material, the depth of the working, the method employed, or the nature of the country in which the deposit occurs. However, for the purpose of this discussion no detailed classification of deposits will be given. Instead a brief outline of those features that tend to classify the deposit and that influence the method of working it will be given.

Variation in the Nature of Materials and Their Occurrence. Clays occur massive or laminated; they occur in thin, 3-foot (*See* Workings Nos. 1 to 8) beds and in beds of great thickness; some contain vagrant stone (*See* Workings Nos. 1 to 8), others are free; they occur interbedded with sand layers and layers of silt or they may have beds which vary not only in their burning colour but also in their general properties (*See* Workings No. 10).

Shales also occur massive (*See* Workings No. 18) or laminated (*See* Workings No. 24). The deposits worked are usually of considerable thickness; they may occur interbedded with undesirable rock (*See* Workings No. 24); some are soft and some are hard, and, like clays they may vary in their physical and chemical characteristics (*See* Workings No. 32).

Both clays and shales occur in level and hilly country, under light and heavy overburdens. Clays and shales show wide variations in toughness and hardness, and ease with which they may be won.

Development of the Workings. In many instances desirable shales in eastern Canada occur underlying heavy mantles of more recently deposited material and are inaccessible by surface workings. The clay at St. Remi d'Amherst was at one time won by underground mining and it is possible that in the future both this deposit and the fireclay deposits in northern Ontario may be worked in this fashion. However, all the present clay and shale operations in the provinces of Quebec and Ontario are surface operations and the general methods by which they are developed and worked vary one from another depending upon:

1. The character of the country.
2. The magnitude of the operation.

PLATE I

Typical clay-working development in level country.

Level Country

There are quite a number of clay and shale deposits operated throughout Ontario and Quebec which are located in level country. They can be divided into two general classes:

1. Deposits where the desired material lies in beds of great thickness. (*See* Workings No. 38).
2. Deposits where the desired material lies in very thin beds. (*See* Workings Nos. 1 tc 8).

Deep-bedded Clays

In deposits of this type where the clay occurs in beds six feet or more in thickness the removal of water from the excavation is one of the greatest problems. Many workings have no means available for proper removal of water, the usual practice being to dig the hole bigger and deeper as the demands of the plant for material increase. Plate I shows a typical development.

When a hole becomes flooded it is abandoned and used as a reservoir. By the time the second hole is opened the problem of drainage is considered and a pump is placed in the new working to remove the water to the first hole. This procedure has been developed through necessity rather than forethought and, consequently, the reservoir is frequently in an inconvenient place for the utilization of the water and is an obstruction to the clay-winning operations.

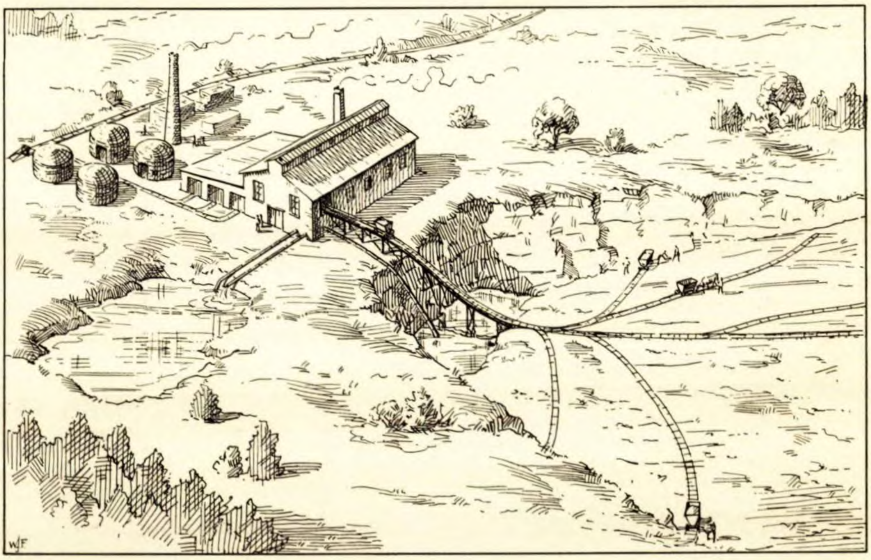


Figure 1. Drawing showing suggested development in level country.

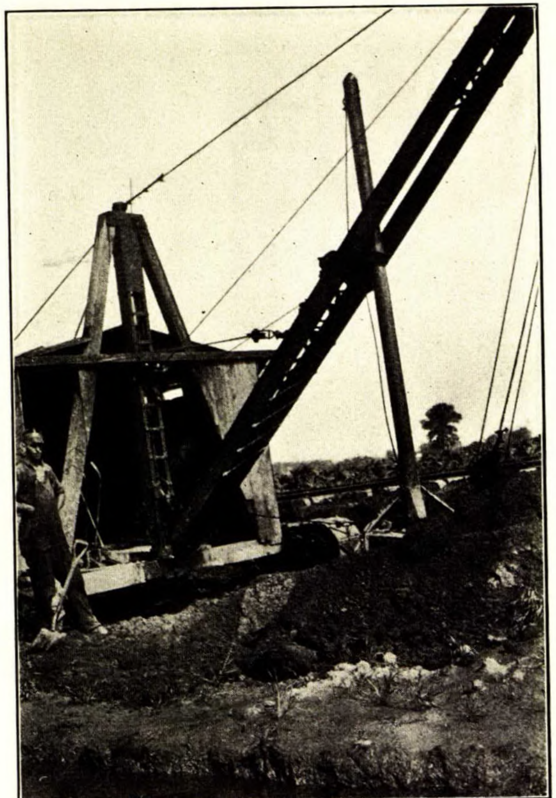
Since two things are obvious, first, that water will be needed for manufacture, and second, that water will be troublesome in the pit, the following system of development is suggested:

When the plant is first put into operation, clay is obtained from a point located in a convenient site for a reservoir. When this pit has been dug to a sufficient depth and capacity, the clay pit proper is opened. Wherever possible this should not be less than 100 feet from the plant. The clay is developed as shown in Figure 1, with a deep sump near the plant.

The working is then developed so as to permit of drainage to the sump, from which the water may be pumped to the reservoir and thence

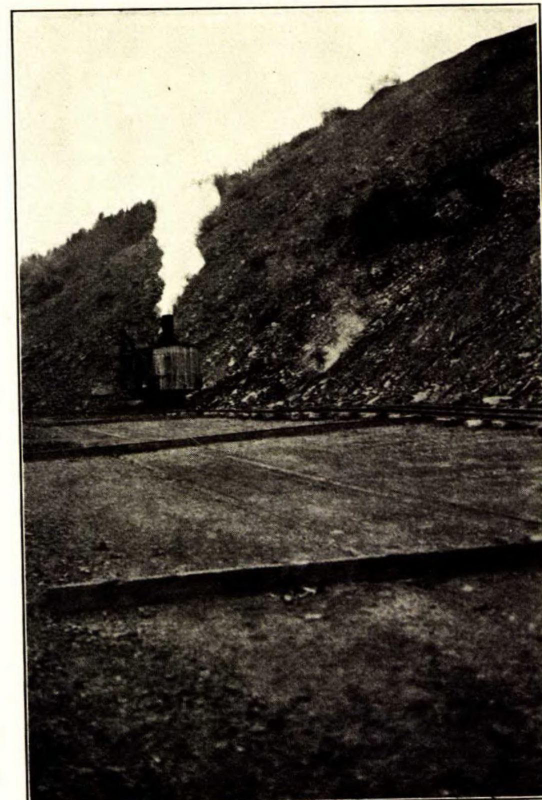
93494—2½

PLATE II



Typical method of winning clay in southwestern Ontario.

PLATE III



Working a large hill of shale.

for use to the plant. With this type of development a permanent trestle can be made as it will be used as placed for a considerable time. This simple layout should save considerable time, as well as money, during wet weather, in that it allows easier working and affords a better opportunity for utilizing the greatest amount of available clay.

Shallow Workings[1]

In southern Ontario the clays lie in beds a little more than 36 inches thick. They could not be operated in the manner just described. The usual method employed in this section is to make a cut 30 feet wide, and at the base of this cut carry a trench approximately 24 inches wide and 24 inches deep as a drain. (*See* Plate II). The cars are usually carried on tracks mounted out of the workings, as shown in Plate II.

These trenches act as reservoirs for the water and assist materially in keeping the workings sufficiently dry. At places where such provision is not made, considerable difficulty is experienced with water. This type of working gradually takes in considerable area, and it is not an economical clay deposit upon which to erect any plant of considerable size, for it is not long before haulage becomes a big factor and money is tied up in depreciated land.

At one plant visited in Quebec the following general system is employed on a shale working of fairly high daily tonnages. Although the shale lies in a fairly deep bed the operating company finds it expedient (for weathering purposes) to work a considerable acreage. A heavy power shovel traverses the area, digging the shale and placing it in heaps to either side where it is allowed to weather for from three to five years. It is then loaded by a smaller shovel into cars for delivery to the plant. The water which accumulates is allowed to follow very much its own course, excepting when it lodges where the machines are working and at such times small trenches are made to withdraw it from that place.

Hilly Country

By far the greater number of clay and shale operations in Ontario and Quebec are located in rolling and hilly country, and the desired materials are usually in the uplands.

The usual layout under these conditions is shown in Figure 2.

A trestle is shown in Figure 2, but quite often the pit floor is on a level with the plant and the need of a trestle is eliminated. The workings should be free of water, but it is surprising to find many where water-holes are plentiful. A very slight grade or trench would afford good drainage but there are many workings where such provision is neglected.

With a high hillside exposure of clay or shale it is often more advantageous to work an expansive face rather than to develop a pit. In three operations in Quebec and Ontario (*See* Workings Nos. 19, 44, and 46) a

[1] See Workings Nos. 1 to 8.

satisfactory method has been to cut from the face, allowing the material to slide or fall down to the base. In such operations slides of the bank

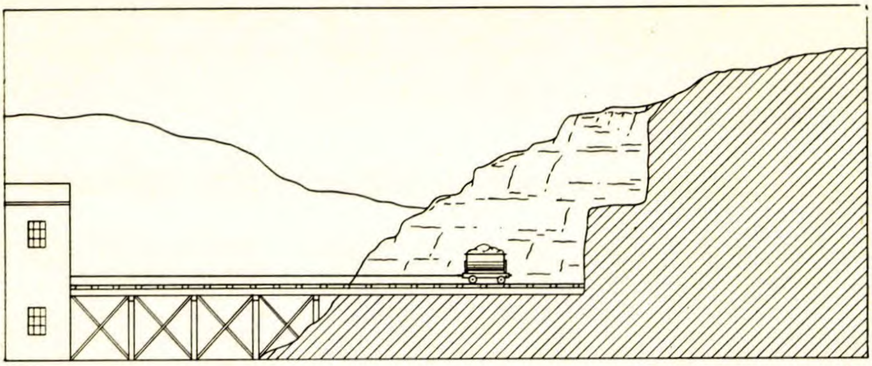


Figure 2. Diagrammatic cross-section showing typical development in hilly country.

are liable to occur, and if the plant is located at the base of the exposure care is needed in blasting and undercutting. (*See* Plate III.)

Development of a Working

The method of development is affected by the presence of overburden, required daily output, wetness of clay, drainage, presence of stone, need of weathering, desirability of benching, and the desirability or need of blasting.

Removal of Overburden

(References 47, 61, 78, 83, 120, 186)

Only a few plants in Ontario and Quebec have a serious overburden problem to deal with, for at most deposits the overburden is less than 2 feet and is usually removed by hand, being thrown into worked-out sections of the workings. The several operations studied that have rather heavy overburden to contend with use a separate power shovel for the work and have transportation equipment similar to that used in their winning operations. (*See* Workings Nos. 25, 32, 33, 34.) The cost of removal of overburden was found to vary from 2 to 25 cents per ton of desired material, the cost being in direct relation to thickness removed and approximated 1·2 cents per ton of desired material per foot of overburden.

The stripping of overburden from clay beds has been developed but little when compared with such operations in the winning of other minerals. There are two outstanding reasons for this fact, first the value of clay, and second, the smallness of the great majority of clay operations. However, the work already done in stripping operations and their evident economies, especially in the mining of coal and iron ores, lead one to expect a greater amount of this type of working in the future and gives one courage to attack deposits which due to heavy overburden and poor roof, have previously been considered to be of little value. One is apt to give considerably more thought to the removal of heavy overburden than to underground mining when one realizes that the stripping of coal in the United States increased seventeenfold between 1917 and 1930; that the average production per person employed per day is 13 tons as compared with 4·6 tons in underground work; that some of the beds operated in this fashion underlie limestones and hard shale; that the ratio of overburden to coal seams runs as high as 16·9 (averaging between 5 and 10); and that the coal was obtained more cheaply than by underground workings.

In Canada, to-day, there is little need for the removal of heavy overburden, although some deposits will have to be worked in this fashion. With the increased production and with centralization of the industry new deposits will necessarily be opened, and deposits which, due to heavy overburden, were regarded useless will be considered from the angle of a heavy stripping operation.

In heavy stripping operations the following are important considerations:—

1. The part of the overburden that may by study be utilized in the manufacture of the product.

2. The disposal of the overburden in such a position as to eliminate several handlings.

3. The utilization of old workings.

4. The removal of overburden by contract. (*See* Workings No. 33.)

For the removal of light overburden, which can be done during one or two short periods during the year and allow work to progress, the availability of a machine on the working, inasmuch that it can be utilized to remove the overburden, is sometimes advantageous. The power shovel, the drag scraper, and the boom dragline are particularly adaptable to this usage. If special equipment is required a dragline or a scraper is particularly applicable.

Plate IV shows a machine which is particularly suitable to the placing of overburden. Where overburden is a real problem a machine of the foregoing type might be most applicable to this condition. (Reference 78.) This machine allows for disposition of the overburden at a convenient place. It is not a digger, but a portable conveyer.

Required Output

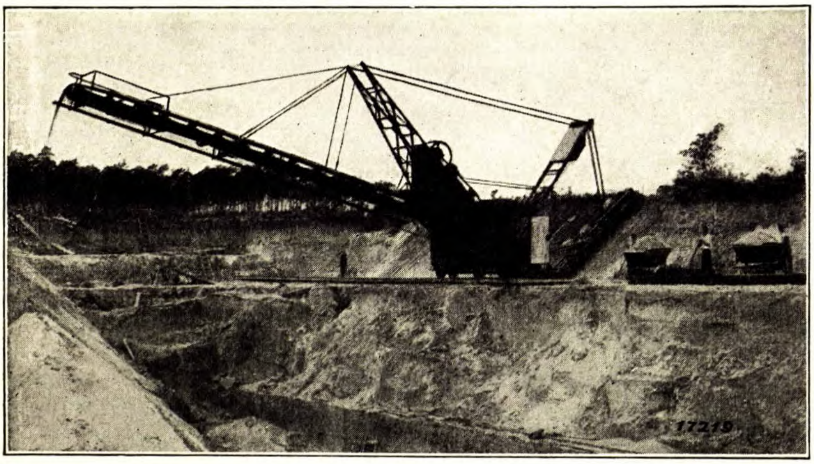
In a clay plant the daily consumption of clays and shales ranges from 12 to 500 tons, and regardless of whether the plant is small or large, steadiness of output is of paramount importance. Storage space is seldom provided for, or at best is very limited, so that the regularity of the plant's operation is dependent directly upon the clay-winning operations. Therefore, in opening a deposit this factor will govern to some extent the choice of equipment, the amount of hand labour, and the size of the working. These should be such as to allow the desired steadiness of output.

PLATE IV

Courtesy: Greenville Mfg. Works, Greenville, Ohio.

Machine applicable to the placement of overburden.

PLATE V



Courtesy: Orenstein-Koppel, A. G., Berlin, Germany.

Machine applicable to digging and removal of overburden.

Wetness of Clay [1]

(Reference 36)

A clay which is too wet to flow properly through the clay-working machinery should not be delivered directly into it without the addition of dry clay. Therefore, anything that can be done in the winning operation from a wet deposit to reduce the water content of the clay is advantageous. In winning wet clay it is desirable and expedient to take full advantage of natural drying forces (sun and wind) in the working. In order to do this the main objective should be the exposure of as much as possible of the clay surface to the elements, and the manner in which the deposit is worked determines very largely the extent of this exposure.

For instance, Plate XIII shows a working where a clay gatherer is used for this purpose. A large surface area is exposed and only a small depth of clay (the depth of a furrow out) is removed at one traverse of the machine. Plate XV shows the ditcher at work on a fairly well exposed surface, taking a very fine cut of the clay at one cut and allowing the face once again to dry out. Planers (Plates XIV and XVI) also allow much the same sort of treatment in different fashions and, therefore, are the tools which are of particular value in this type of working.

The study at Workings No. 45 shows that the presence of too much moisture may add considerably to the winning costs.

Drainage

(References 24, 28, 41, 80, 138, 140, 146, 182, 186, and 291)

Drainage in workings does not always receive the attention it should. In some workings where drainage is absolutely necessary, provision has been made, but many operations have made no provision for drainage whatsoever.

Drainage is most important where the excavator works in the pit (*See* "Types of Equipment") and when it loads into cars in the workings; if wagons or trucks are used (that is, vehicles not running on tracks) the importance greatly increases.

In level country drainage can be carried out successfully by a series of ditches. (*See* Plate II.) At one deposit these are connected up and drained by means of a mechanical pump.

Pumps are used where pits are deep and there seems to be no reason why every operation should not be equipped with such a machine since much better working conditions can be obtained at an economical cost.

In most cases a combination sump, to which the pit water is caused to drain by gravity, and a pump has worked most satisfactorily. The type and capacity of the pump will depend entirely upon local conditions.

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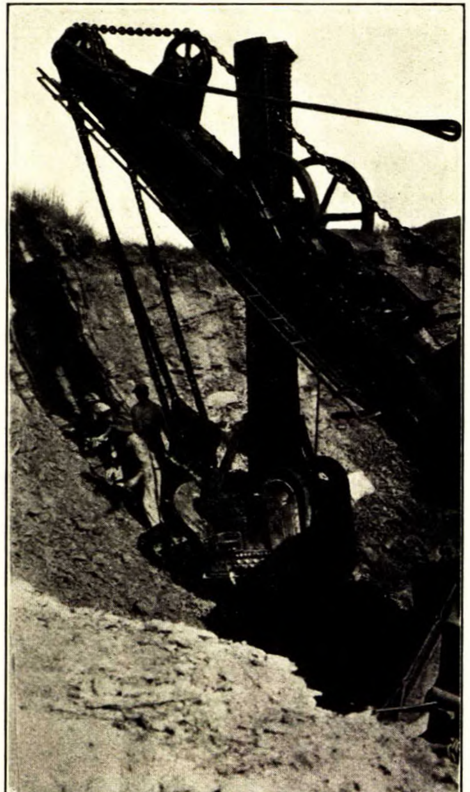
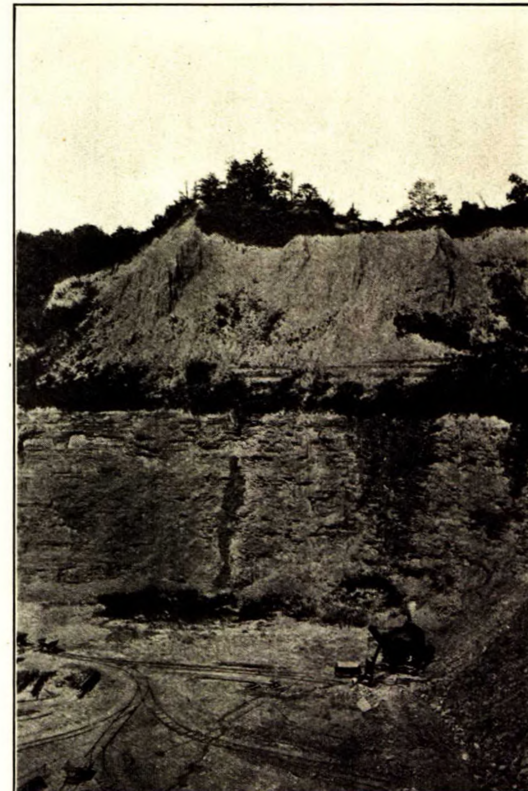
[1] (*See* Workings No. 45.)

PLATE VI



Hand-picking stone from shale prior to loading.

PLATE VII



Material blasted from height aids in the separation of stone.

Presence of Stone

(References 36, 163, 164, 170)

When the shale is interstratified with stone that is detrimental, certain winning operations can be used to aid in its removal.

One Canadian company employs a rather heavy (3-yard) shovel. (*See* Plate VI.) The bucket when filled is raised above the pit, and opened, resulting in a drop of the material through about 20 feet. The fall separates the more friable shale from the rock, leaving the latter in large pieces that may be cobbed.

Another means utilized in Ontario and Quebec is weathering (*See* Workings No. 38), which causes a certain amount of slaking of the shale but does not appreciably affect the stone. The slaked shale is then easily separated from the hard stone. At one plant the shale is worked with a wide face exposed to the weather. The shale is blasted down from a height which, together with time for weathering, assists materially in the separation. (*See* Plate VII.)

Although these methods do not rid the material of all the stone they assist in removing much of the larger stones. Small pieces of stone are removed at the plant in the process operations.

As shown in Plate VIII small stones in clays are often watched for and removed during the loading operation (southwestern Ontario).

Desirability of Weathering

(References 33, 82, 239, 246)

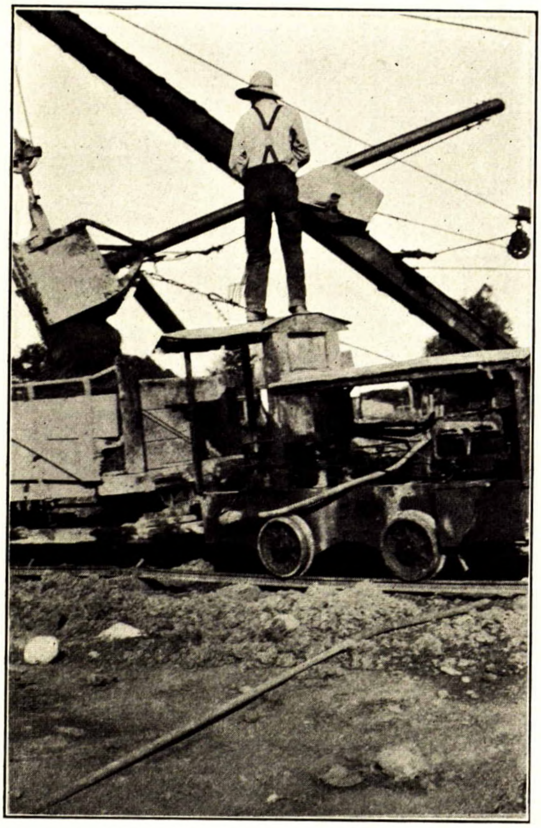
Weathering is desirable when stone is present and when the material is hard and not very plastic. Not only does weathering assist in the removal of stone but, by breaking down the material, assists in the grinding operation and also increases plasticity. (Shales are weathered in several workings in Quebec and Ontario, weathering time in one case amounting to 5 years.) The working of a deposit so as to maintain a large face assists weathering to some extent but the most effective method is to break up and remove the material, either by blasting or digging, and, after it has weathered sufficiently, it is dug again for plant consumption. This sometimes requires a separate crew. Workings No. 36 indicates that some weathering methods are expensive.

Desirability of Benching

Benching is employed in the following types of workings: (*See* Plates VII and IX).

1. Where sections of the clay bed have different physical and pyrophysical properties (*See* Workings No. 32). Many deposits of clay and shale that are buff-burning in the lower sections are red-burning in the upper sections due to the leaching out of the lime. (This occurs in Ontario and Quebec.) The sections may vary also in their plasticity and general burning properties. In such cases it is often possible to separate the different sections by benching.

PLATE VIII



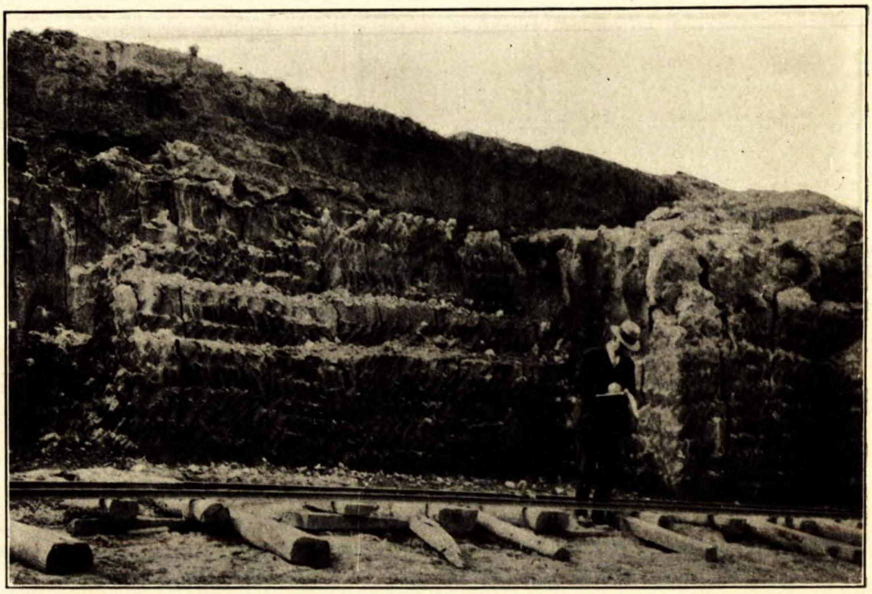
Removing stone as clay is loaded.

2. In workings where hand labour is employed and explosives not used (*See* Workings No. 45), digging is much easier with the use of benches. Benches vary from 5 to 7 feet in height in hand-dug operations.

3. When the face of the pit is so high that blasting of the whole face is not expedient, benching is resorted to so as to control the breaking down of the face. The best height for blasting benches is given as 25 to 28 feet (*See* Reference 65).

4. Where production is such as to require two or more crews working at the same time.

PLATE IX



Method of working clay deposit by benching.

Drilling and Blasting

(References 17, 73, 149, 252)

The use of explosives is more general in shale workings than in clay workings.

In shale workings where the material is hard and the equipment is such that it will not remove the shale (*See* Workings No. 30) blasting becomes necessary. In those shale deposits where weathering is desirable (*See* Workings Nos. 22 and 24) or, where the shale is interbedded with hard stone, blasting is expedient and advantageous. In deposits where the shale is not blasted it is dug either with a large power shovel (2 to 3 yards, *See* Plate VI), or with a planer. In the provinces of Quebec and Ontario blasting is done in all but two shale workings.

In clay deposits the use of explosives depends to a large extent upon the type of equipment and the nature of the material, although the daily tonnages and depth of face worked have some influence upon their use. Explosives are not used when the clay is wet, nor are they used when the depth of clay is under 10 feet, nor when equipment such as scrapers or planers is used. They are used in connection with power shovels, not because they are always necessary but because they lessen the work of the shovel considerably. Explosives are often used where hand-loading is employed, but on the whole the advantages of their use in clay workings are not so great as in shale.

TABLE I

Blasting Practices in Representative Ontario and Quebec Workings

Plant No.	30	22	33	26
Material won	Shale	Shale	Shale	Clay.
Type of drill	Hand	Air	Air	Hand.
Diameter of hole	$1\frac{1}{4}$ inches	2 inches	$1\frac{1}{4}$ inches	2 inches.
Depth of hole	4 to 9 feet	6 to 8 feet	12 feet	3 feet.
Direction of hole	Vertical	Vertical, horizontal, slanting.	Horizontal	Horizontal and vertical.
Explosive	40 per cent	40 per cent	40 per cent	40 per cent.
Explosive per hole	1 stick	6 to 8 sticks	20 to 40 sticks	1 stick.
Holes per day	2 to 4	30	3	Varies.
Frequency of blasting	Daily	5 days per week	Twice per week.	Daily.

Plant No.	24	32	46	44
Material won	Shale and clay	Shale	Shale	Shale.
Type of drill	Air	Electric	Air	Air.
Diameter of hole	2 inches	$1\frac{1}{2}$ to 2 inches	$1\frac{1}{2}$ inches	$1\frac{1}{2}$ to $2\frac{1}{4}$ inches.
Depth of hole	8 feet	4 to 20 feet	10 feet	6 to 8 feet.
Direction of hole	Vertical	Vertical and at angle.	Horizontal, vertical, at angle.	Vertical.
Explosive	40 per cent	60 and 40 per cent.	60 per cent	60 per cent.
Explosive per hole	12 sticks	Varies	4 to 8 sticks	5 sticks.
Holes per day	8	1 to 10	Not regular	Not regular.
Frequency of blasting	Daily	Not daily	Twice per week.	Drill as convenient.

With few exceptions the problems of blasting receive little special attention. The operation is usually carried on by men whose experience has been gained in the workings in which they are employed, being guided to some extent by the plant superintendent and the explosives manufacturer. (References 29, 85.)

For drilling shales the air hammer has found a very wide use and the electric drill is popular. The hand drill still has adherents and the rotary well-drill is used to some extent. (References 81, 201, 223, 234, 244.) Of 100 plants investigated by Brick and Clay Record (U.S.) the following types and numbers of drills were found in use: hand drill, 44; electric drill, 43; well drill, 8; air drill, 4; and steam drill, 1.

Owing to the fact that the dynamites (References 26, 31, 136, 261, 267, 269, 278) obtainable to-day are of such regular quality, so easily manipulated, and that there is a large amount of information regarding handling (References 148, 149, 172) and use, they are gradually replacing black powder even in clay workings. Black powder, however, is still popular due to its slowness of action and consequent lifting property. In the blasting of shales dynamite is used almost exclusively, the usual strength being 40 per cent but some operators use 60 per cent.

By referring to Table I, the general blasting practices in some Ontario and Quebec workings will be seen. Practice varies, however, and the reason is apparent when one realizes the differences that exist in the workings.

At Workings No. 30 the shale worked is massive and fairly hard with a pit face approximately 10 feet high. The quarryman not only does the drilling and blasting but assists in loading the shale by hand into cars. The daily capacity of this operation is approximately 50 tons.

At Workings No. 22 the shale is hard and massive and the average daily output is 300 tons, one man is allotted to the blasting job. The pit face is approximately 20 feet high.

Workings No. 33 has a pit face of approximately 40 feet. The shale is very hard and contains considerable stone strata, one of the pit crew handling the blasting.

Workings No. 26 is a clay operation located in a residential district where heavy blasting is undesirable. One man is usually allotted to carry on this work.

At Workings No. 24 the shale is hard and laminated and associated with considerable stone strata. The face of the pit is 60 feet and is worked in benches. One man is in charge of drilling and blasting operations. Shattering of the shale is desired in order to separate the stone.

The material in Workings No. 32 is a fairly massive shale which varies in hardness from top to bottom. It is worked in benches approximately 20 feet high and one man is in charge of the drilling and blasting.

Workings Nos. 46 and 44 are operations at which the shale has a decided tilt. (*See* Plate X). As the plants are very close to and below shale banks, blasting must be done with care.

In general the blasting problems of the clayworker are to throw the material down in such a condition as to be easily loaded by the means employed; to keep the pit bottom in as level a condition as possible; and when blasting near the plant or buildings, to control his shooting. These are solved by varying the distance of the holes from the face, varying the depth of the holes and the amount of explosive. It often pays the shale winner (*See* Workings No. 29) to contract for his blasting operation with some concern whose business it is, and this practice is particularly applicable to workings wherein blasting is done for weathering purposes. In clay and some shale workings, however, the cluttering of the pit with an excessive amount of blasted material would be a distinct disadvantage. Where blasting is done by contract, it is done from one to three times a year, depending upon the demand.

One particular operation (Reference 59), due to lack of electric power or air power, finds it advantageous, at the end of each day's work, to attach a drill to the steam shovel boom and use steam for drilling holes.

Liquid air for blasting is not used in the clay industry although it is becoming popular in other mining operations (References 1, 56, 69) where large masses are blasted at once.

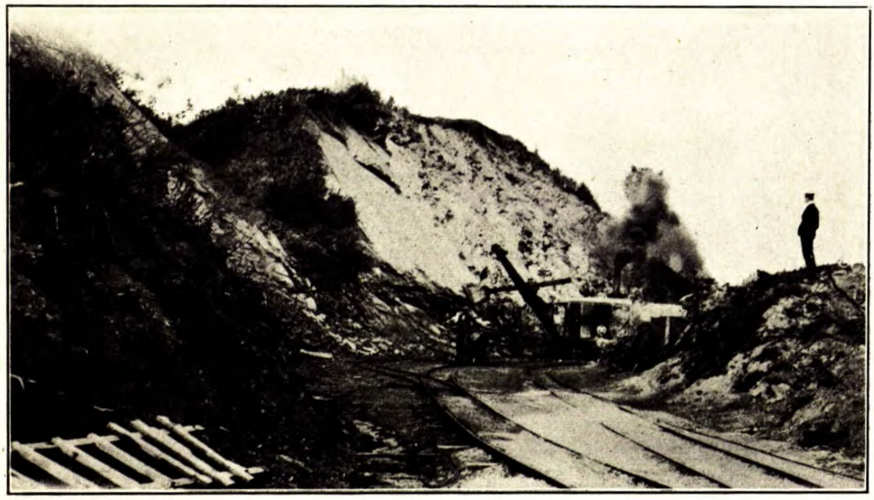
Springing of holes is used only where large masses are blasted at once and not resorted to, to any extent, in the winning of clays or shales.

The clayworker's problems in connection with blasting are varied and it is impossible, without considerable specific study, to write a set of rules to be followed for all clay and shale workings.

Generally speaking the following rules are given by Paoli: (Reference 234).

For faces up to 7 feet, holes should be placed back about 6½ feet and be 6 feet apart.

PLATE X



Working tilted shale beds.

For faces from 14 to 20 feet, holes should be placed back 6 inches for every 1 foot of height of face and equally distanced. That is for a 20-foot face, holes should be 10 feet back and 10 feet apart.

Holes for lifting purposes should be drilled below quarry floor.

For inclined shale beds, horizontal holes near floor are advantageous.

Well drills with from 4- to 4½-inch bits are satisfactory where faces are more than 25 feet.

One half pound of explosive should be used to the cubic yard in the solid in drill holes that are 10 feet or more deep. If hand-digging, more may be used to break up the material.

Having fully considered all the foregoing factors, decision can be made as to the amount of hand labour to be utilized and the type of equipment to be used.

Labour

(References 6, 124, 156)

Unskilled labour has always been utilized in the winning of clays and shales, but it is gradually being replaced by mechanical devices. Many plants still employ unskilled labour throughout and do so economically, but these are, for the most part, plants that operate for only a few months in the year. The work done in the clay pits by unskilled labour includes the following; digging clay, loading clay, loading shale, blasting, removing stone, breaking shale lumps, cleaning up around machines, pushing cars, and driving and caring for animals.

Wage incentives have been found advantageous in many operations of the ceramic industry. (Reference 211).

Skilled labour is required for the operation of various types of machines, but this will be discussed under equipment.

It is interesting to note that plant operators often have directly opposite views on the question of unskilled labour; one will say that he would not have a man breaking his back in a clay pit for any reason, while another will say "I would rather give a man an opportunity to earn his living than have a machine do the work, regardless of cost." Digging clay and working around a clay or shale pit is usually heavy and arduous work but it is not infrequent that men can be pointed out who have dug clay for 20 or 30 years and who, at the age of 60 or thereabouts, are in good physical condition.

The unskilled labourer, however, is gradually giving way to the skilled labourer with mechanical equipment, and on most large workings this has already taken place, except in those deposits where particular work such as separation of stone is required. Hand-digging is illustrated in Plate IX, and Plate VI shows men removing stone from shale. Barnes states that where 40 yards or more of clay is needed per day a power excavator is applicable. (Reference 87).

Machinery and Equipment

(References 21, 32, 33, 52, 54, 55, 60, 63, 64, 86, 91, 110, 113, 119, 121, 151, 155, 168, 169, 185, 203, 212, 218, 231, 236, 237, 254, 277, 286, 290).

For many years the only types of equipment used by the clayworker in the winning of his raw material were picks and spades. He has, however, kept fairly well apace with developments and has tried almost every type of excavating equipment available, regardless of whether the equipment was originally designed for building roads or for digging ditches. The application of various types has played an important role in allowing him to control more closely his problem of obtaining steady output of uniform material at an economical cost. The power shovel is the only piece of equipment he has accepted wholeheartedly, and consequently it is seen in the majority of clay and shale workings.

The machinery used to-day may be generally classified as follows:—

1. Power shovels (References 87, 195, 208, 292) taking rather deep cuts from the vertical.

A. Steam—most common. (References 77, 115).

B. Electric—fast becoming popular. (References 30, 77, 270).

C. Gasoline—fast becoming popular. (Reference 270).

2. Scrapers—taking rather deep slicings (6 to 8 inches) from the horizontal or slope. (References 52, 186, 249, 272).

A. Wheel scrapers, animal-drawn (transporting).

B. Wheel scrapers, tractor-drawn (transporting). (*See* Workings No. 13).

C. Cable-drawn (transporting). (References 35, 38, 89, 213).

D. Working from boom (not transporting). (Reference 11).

3. Planers—taking a thin slice from the horizontal, slope, or vertical. (Reference 12).

A. Clay gatherer. (*See* Workings No. 21).

B. Shale planer. (References 57, 221, 274).

C. Clay planer—

i. Endless belt type. (Reference 91).

ii. Wheel type. (References 186, 222). (*See* Workings 23).

4. Others—dredges, clamshells, etc. (References 23, 160, 263).

Power Shovel. By far the most general type of excavator used in the clay industry is the power shovel, which has been and is used in all types of operations. The power shovel has been developed for digging and loading, but where selection is required it is not always the most suitable piece of equipment. It is particularly applicable to loading either clay or shale; it will dig clays and shales, but if these are first loosened by blasting more efficient work can be done. Its particular value lies in its capacity for work and its flexibility of movement. Its principal use is in hilly country or to dig pits in level country. Steam, electricity, gasoline, or oil is utilized for power, the majority being operated by steam; however, many of the newer machines are operated by electricity, gasoline, or oil. The buckets carried by shovels vary from three-eighths of a yard to three yards, the majority being three-quarter yard and under.

The following data on shovel operation are taken from Brick and Clay Record, (June 21, 1927).

Type of Shovel	*Fuel Consumption*
Steam	1 ton of coal per 500 to 600 tons material.
Gasoline	1 gallon to every 12 to 15 tons material.
Electric	0·3 to 0·6 kilowatt hour for each ton of material.

No. of Plants	*Type in Use*
43	Steam.
21	Electric.
8	Gasoline.
1	Gas-electric.

No. of Plants	*Size of bucket, yd.*
2	$\frac{1}{4}$
2	$\frac{3}{8}$
3	$\frac{5}{8}$
67	$\frac{3}{4}$
2	$\frac{7}{8}$
4	1
1	$1\frac{1}{4}$
1	$1\frac{1}{2}$

Scrapers. Scrapers, both animal- and power-hauled, are used to some extent in the winning of clays, but the workings which they develop are poor and are apt to become unsystematic. They are particularly adaptable where close control of the material used in the manufactured product is not essential. They are usually used on small operations whose yearly run is from 3 to 5 months.

Scrapers, Wire-hauled. (Operated out of the workings—Reference 272). The drag scraper is used to some extent in the winning of clays. It is applicable to both hilly and level country, the majority in use being in the former. It is valuable as a remover of overburden or of a very light clay bed (Plate XII), and it has been used to tear down large banks of clay. In the latter type of workings, the equipment is not selective and develops a ragged, sloping face. However, when worked on a thin clay bed, as shown in Plate XII, the quality of the clay is fairly well controlled.

One workings (U.S.) (Reference 21) removed 500 tons of clay per day at a cost of 0·04 cent per ton—$24 was daily operating expenses including depreciation.

This type of excavator has found use in some clay workings. It is particularly advantageous for removal of overburden. for clay removal in rough country, when water is very troublesome, when production is high, for weathering material, and for removal of loose earth. The disadvantages of this type of excavator may be summed up as follows: It is not the best type of equipment for obtaining cross-sections of a deposit. It is not applicable to Canadian shales. On level ground it develops a wet working.

Scrapers, Boom-type. (Operated out of workings—Reference 11). A boom carrying a scraper is sometimes mounted on a power shovel chassis. This type of equipment is not used to any extent in the winning of clays and shales, but could be used to advantage on shallow deposits in level country or for the removal of light overburden.

On one large installation in the United States, one operator removes 210 tons of overburden and 420 tons of shale per day. The machine is equipped with a 1-yard bucket and operated by a 52 h.p. motor; it is moved and turned with a 37 h.p. motor. Another, having a 110-foot boom and a 2-yard bucket, removes sufficient clay for the manufacture of from 250,000 to 300,000 brick daily.

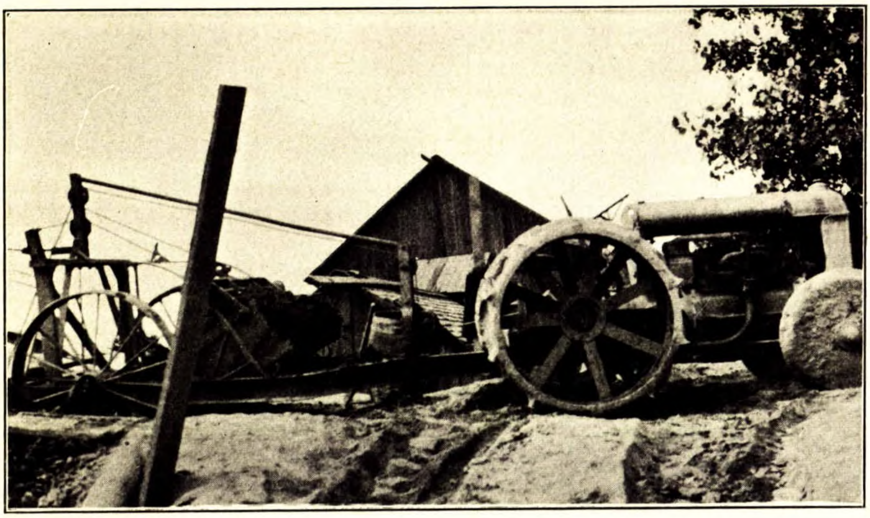
Fuel consumption is given (Reference 11) as follows:—

Coal, 4 to 6 pounds per cubic yard..	Average digging.
Oil, 0·3 pound per cubic yard..	
Electricity, 0·3 to 0·5 kilowatt hour per cubic yard.. ..	

Clay Gatherer. (*See* Workings No. 21). The clay gatherer is a horse- or tractor-drawn machine which picks up the loosened clay (loosened by harrow usually) and carries it in a steel drum. When full it is hauled to a tipple where it dumps the clay load into vehicles. It will be noted that this type of machine develops a working that exposes a large area to the elements; as the digging done is shallow, there is necessarily a great expanse of ground under operation.

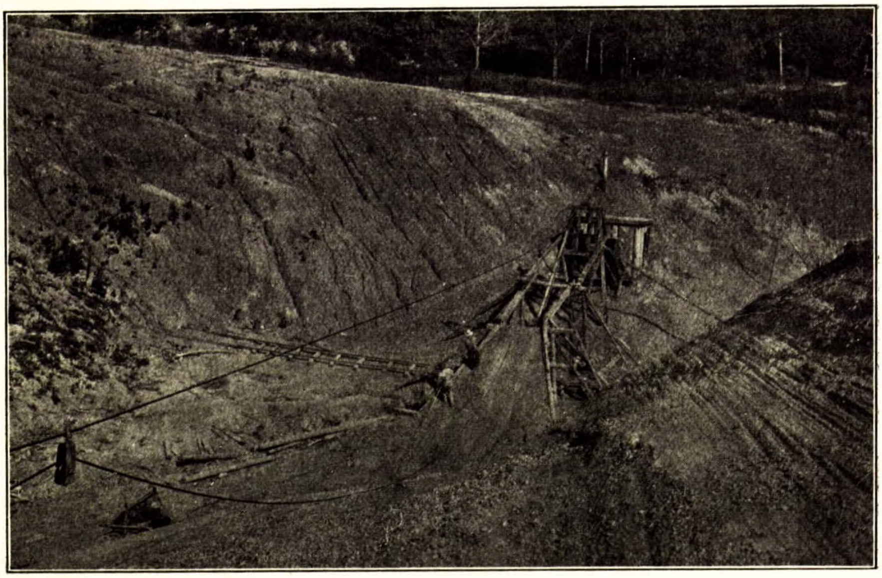
This particular type of equipment is suitabe to level and slightly rolling country, and is of particular advantage in clay operations where weathering is desirable or where ground water is a problem. It is usually

PLATE XI



Tractor-drawn wheel scraper.

PLATE XII



Drag scraper operating in thin clay bed.

used on small operations, though it is also used as auxiliary equipment on large operations. It is applicable to the removal of light overburden. One clay gatherer (Reference 21) hauling over a distance of 300 feet delivered 124 cubic yards (121 tons) of clay in one day, carrying ½ cubic yard of material per trip and having wasted time amounting to 15 per cent.

Shale Planer (Continuous belt type—operated in the workings). This type of mechanical digger has found popularity in certain types of shale operations, and for plants working to full capacity has proved very economical. It consists essentially of a steel structure carrying an electrically-driven, forged steel chain that is forced against the wall of shale (working either up or down) thereby knocking the material loose from its bedding. The material drops to the base of the structure where it is carried by an endless belt to either hoppers or vehicles. The machine works either in a straight line or cuts a circular swath through 180 degrees, the latter being preferred due to the lessening of chances for slips. The face developed approaches the vertical but can be made to develop a slope (68 degrees from horizontal). It moves automatically, removing from one-half to one inch of shale at a time. It can be operated on a face from 20 to 80 feet in height.

PLATE XIII

Horse-drawn clay gatherer.

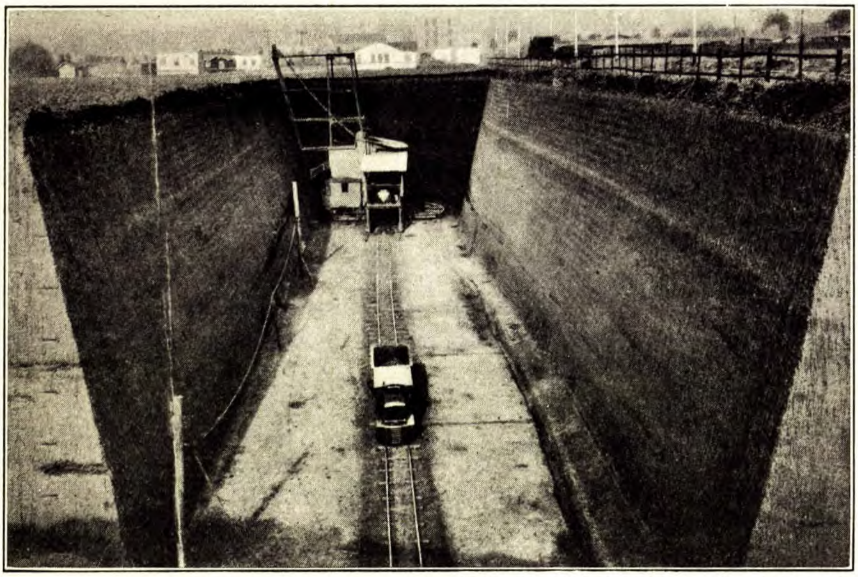
This machine is particularly adapted to workings where a face is already developed and a uniform cut is desired and where high daily tonnages are required. The materials upon which it has worked successfully range from soft to hard shales. It saves considerable in crushing and grinding since it delivers the material in small pieces. It will deliver dry shale on rainy days and can be worked in the winter months.

Its disadvantages are that it develops a rather long face which, if high, gives opportunity in readily-weathering shales for slips, and that it is not a flexible unit. Moreover it is a difficult machine with which to open a deposit.

Its value on hard massive shales, such as occur in Quebec and Ontario, is doubtful; where limestone strata are present or where the beds are tilted (Plate X) it would be at a disadvantage.

C. F. Tefft (Reference 274) states that for the production of 100,000 brick per day a shale planer will carry depreciation and repair charges amounting to $12.50 per day and that the labour charges will be equal to those on an up-to-date shovel operation.

PLATE XIV



Courtesy: Eagle Iron Works, Des Moines, Iowa.

Shale planer.

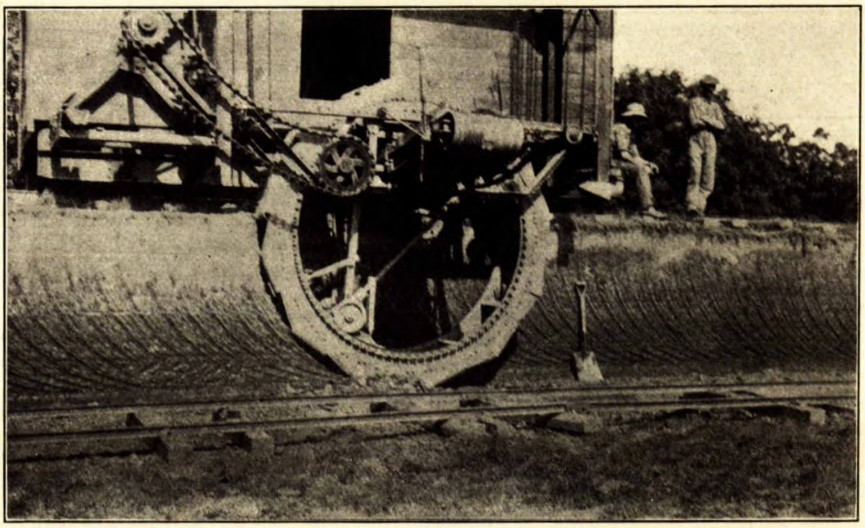
The use of a conveyer discharging to a more or less permanent separate hopper was found to aid in lessening chances of cave-ins and to afford better opportunity for capacity cutting, thus adding greatly to the efficiency of the machine. (Reference 57).

Ditcher. (Operated out of the workings—*See* Workings No. 23). The ditcher is another machine which develops its own particular type of working. It is a combination digger and loader. It has been said that it will work on some shales but the writer has seen it in operation only on clays where it has proved very successful. The machine can develop a face to a maximum height of 10 feet and takes a cut from the face ranging from 1 to 12 inches depending upon the requirements and the machine.

The ditcher is applicable in level and slightly rolling country and it is of particular value where it is desirable to eliminate certain irregular bands of undesirable material and where uniformity is important. It is a machine which has been used on large operations with satisfaction and economies.

One machine operating in New Jersey loads 80 to 90 cars a day, each car averaging from 7 to 9 tons. (Reference 186).

PLATE XV



A ditcher.

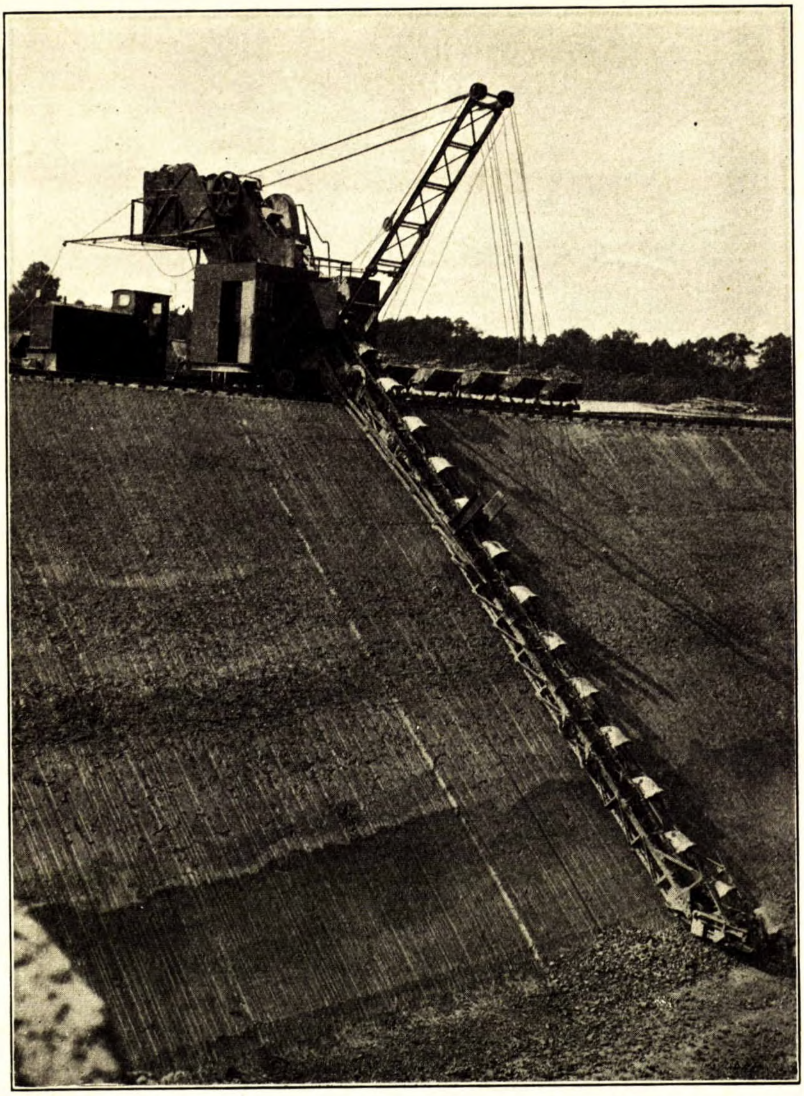
Other Types of Planers. (Operate either in or out of pit. Plate XVI). These types are used in Europe with satisfaction. They are made in various sizes and for various capacities. They are diggers and loaders and offer all the advantages afforded by a representative cut of bank and a wide exposed face. The working developed is a sloping-faced pit which can be kept in good order.

On a small operation (working under English conditions) a manufacturer estimates the following cost of operation of a small machine of this type.

Daily capacity	64 cu. yds. (54 tons)
Number of working days per year	125
Depreciation and interest = 17 per cent of $\frac{\$1920}{125}$	\$2.61
Fuel and lubricant	0.60
Operator's wages	2.40
Maintenance	0.75
Total expenses per day	\$6.36

Power service is usually by electricity or by Diesel engine.

PLATE XVI



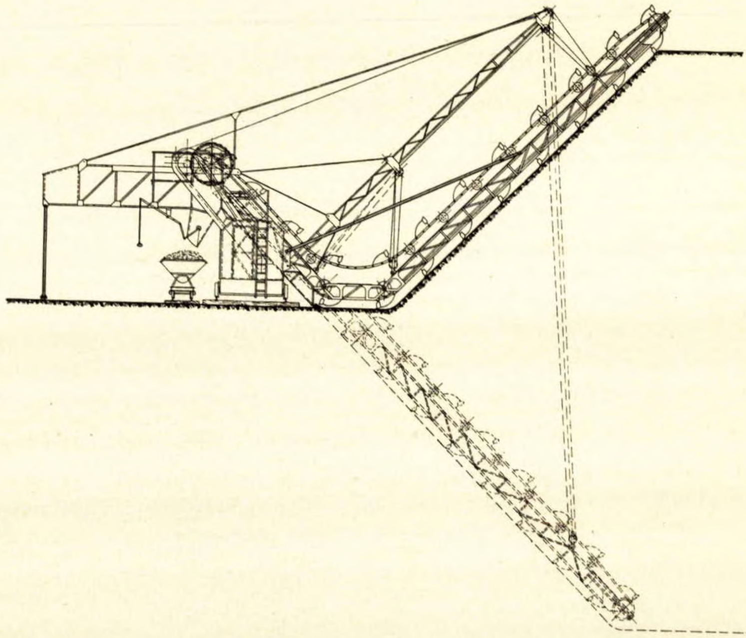
Courtesy: William Jones, Ltd., London, England.

Clay planer.

Estimates in Germany on an excavator of this type were given (Reference 64) as follows:

	Per day
Interest and depreciation (20 per cent of investment)..	$ 15.00
Power, 5 kilowatt hours..	16.50
Wages of operator..	4.75
Wages of dumper..	1.00
Repairs, oil, etc..	16.25
Wages for track labourers..	15.00
	$ 68.50

Winnings 65 cubic metres (85 cu. yds.) per hour.



Courtesy: William Jones, Ltd., London, England.

Figure 3. Sketch showing adaptability of clay planer.

Other Types of Equipment

The clamshell is used in very few clay-winning operations and for a digger it is not highly recommended unless the material is under water, or if the condition of the workings is of little interest or where the selection of clay is unimportant. It develops, as might be expected, a ragged hole which soon becomes a mud hole.

A special type of equipment, which consists of a boom at the end of which are six picks that revolve at 350 revolutions per minute, and which cut a channel 18 inches wide by 10 inches deep, and throw the clay into a conveyer in 4-inch lumps, is said to work very efficiently. It digs downward and makes a slanting face and is applicable to the digging of clays and shales.

Air-operated hand spades (Reference 19) have been used to some extent in Europe for digging clay. The spade is light and handy, cuts either horizontally or vertically with a fairly long stroke, is weather-resistant and is simple in construction. The newer types are automatic in operation, as soon as the pressure is exerted on the handle the air is turned on and as pressure is released the air is turned off. The shapes of the cutting tools vary for different types of clays, some are pointed while others are straight-edged. These spades have been used successfully on hard or stiff clay and other material that usually requires picking. It is calculated that the output is 4·7 cubic metres (6 yards, approximately 5 tons) per day according to the type of material. One man operating the spade can loosen sufficient material to keep two others loading. One tool will use from 21 to 28 cubic feet of air at 5 atmospheres pressure, but when a series of tools work from the same compressor a somewhat lower average consumption may be figured. A 3-cubic metre (105 cubic feet) compressor will be ample for 5 tools.

These tools are said to be useful on overburden, breaking down large lumps resulting from blasting, and for working frozen ground.

Table II gives a general idea of the usual application and operating probabilities of the more common types of excavators used in winning clays and shales.

TABLE II

Application of Types of Excavators to Winning of Clays and Shales

Type of equipment	Nature of country	Daily tonnages	Type of workings	Nature of workings	Pre-loosening	Particular advantage	Loads into	Best suited to	Investment
Gatherer	Level or slightly rolling.	75 and over.	Follows contour of country.	Good	Yes, required	Leaves large area exposed.	Vehicles	Clay	Very small.
Ditcher	Level or slightly rolling.	100 and over.	Straight vertical face.	Good	No	Uniform and controlled cutting; capacity	Hoppers or vehicles.	Clay	Medium.
Drag scraper	Hilly; level or slightly rolling.	100 and over.	Sloping bank; sloping pit.	Ragged	No	Capacity	Hoppers	Clay	Medium.
Power shovels	Hilly; level or slightly rolling	50 and over.	Vertically faced pit.	Good	Desired	Capacity; flexibility.	Vehicles	Clay and shale.	Medium to very large.
Shale planers	Level	100 and over.	Steep-faced pit.	Good	No	Uniform and controlled cutting; capacity	Hoppers or vehicles.	Shale	Large to very large.
Clay planers	Level or slightly rolling.	100 and over.	Sloping faced bank.	Good	No	Uniform and controlled cutting; capacity.	Hoppers or vehicles.	Clay	Variable.
Wheel scrapers	Level or slightly rolling.	75 and under.	Follows contour of country or develops holes	Ragged	No	Flexibility	Hoppers	Clay	Small.

UNDERGROUND MINING

The underground mining of clays and shales is carried on in a number of places. The methods employed are quite similar to those used in coal mining, and factors governing the latter operations are usually applicable to clays and shales. Much attention has been given to underground mining of bedded deposits in the past ten years and much information is available regarding economical procedures under various conditions.[1]

Clays and shales are mined:—

(1) When the material is of sufficient value to warrant such method, for instance, fireclays which are to be used in the production of comparatively high-priced clay products; sewer-pipe clays, the quality of which is superior to those occurring on the surface, or for building brick when the material will produce brick of higher quality than can be had from surface materials in close proximity and can, therefore, command comparatively higher price.

(2) When the ratio of the thickness of desired material to overburden is less than 1 to 3.

(3) When the beds of the material are at least 4 feet in thickness.

(4) When the clay beds occur in association with coal.

There are certain operations where all these conditions do not exist; however, one of these conditions may be so favourable as to permit of disregard of one or more of the others. For example, in one place a fireclay bed is being worked which is only 18 inches thick, but it represents the last reserves from a property that has been producing for years.

Two systems of underground mining are generally followed—the advancing, and the retreating. In the advance system the materials are retrieved as the workings progress; in the retreat system a main entry is forced at first straight through the material to the property limits. R. H. Hearing and C. F. Tefft (Reference 162) advocate a combination of the two systems, utilizing the advantages of each. Both systems involve main entries, room entries, and the use of pillars.

The chief advantage of the advancing system is that the plant begins to benefit from the operation much earlier than in the case of the retreating system. Therefore, it is particularly suited to plants where small tonnages are required and small capital available. Its disadvantage is that considerable timbering (which constantly becomes more important) is required to prevent possible cave-ins on the main entry. Moreover, in deposits where the overlying strata afford poor roofing it is a dangerous system to work unless the loss of pillars is considered unimportant.

The advantages of the retreating system are, first that there is a good main entry provided (the crew not being particularly worried about the material output); second, pillars can be pulled immediately after a room is finished without danger to any of the workings, and a better working knowledge of the deposit is had than in the case of the advancing system. It is particularly applicable to large opera-

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[1] References 3, 5, 8, 10, 20, 21, 27, 43, 52, 53, 58, 64, 74, 81, 90, 92, 98, 99, 112, 113, 117, 119, 125, 128, 129, 131, 132, 137, 142, 146, 150, 161, 162, 167, 168, 171, 172, 174, 175, 176, 178, 180, 183, 198, 199, 215, 216, 224, 225, 226, 227, 228, 229, 230, 233, 235, 236, 240, 253, 256, 257, 258, 259, 265, 266, 283, 293.

tions and to places where the roof is poor and the supporting power of the clay or shale is weak. In the retreating system a greater percentage of the clay is recoverable with considerable less cost in general mine upkeep.

The advantages of the combined two systems is undoubtedly the answer to any progressive clay-mining operation as it entails a small amount of the advancing system at the beginning to provide the plant with material until such time as the main drift has been put through to its limits, at which time the retreating system alone is followed.

Supervision in the mining of clays has in the past been in the hands of practical miners with the assistance of engineers or surveyors hired occasionally to map the mine and the property limits. There is a tendency, however, of late years to place this in the hands of plant engineers with the assistance of a practical mine foreman. The recent investigation carried on by Bole and Nold[1] proved conclusively that in Ohio, at least, closer attention should be paid to supervision; inasmuch as considerable loss was entailed in not recovering the pillars, by poor drainage, by poor trackage, and by loss of timbering.

Miners in this industry are paid in different ways. Some are paid by the hour, some by the month (a few on each operation), and some by tonnage; in the latter case they are often required to purchase their own explosives, tools, etc., and to do all their own timbering. Conditions vary so much and so little information is available regarding the merits of either system that it is difficult to say which is the fairer one. For instance, in the mining of fireclays in Pennsylvania the wages per ton of clay (1930) given to a miner varied from 40 to 80 cents, depending upon the type of clay delivered, various grades of clay occurring as they do one upon the other in the same workings. Anderson (Reference 5) gives wages varying from 18 to 24 cents per ton (1929).

Blasting powder in either powder or pellet form is most popular in underground workings, though dynamite is used to some extent.

Drilling is done by hand auger in most cases, though the use of electric and air drills is becoming popular. Holes are drilled from 18 to 24 inches apart. Large machine drilling is not recommended due to small daily requirements (Reference 5). Two men operating a 3 h.p. drill can make from 50 to 70 holes per day in from 5 to 7 places and provide 400 tons per day.

Blasting is done at the end of the day's work and the material is loaded the next day by hand into wooden end-dump cars. The use of an air-powered shovel (References 27, 52) in several operations has received favourable comment but its general application is questionable. Its cost of operation including labour, repairs, and power is given (Reference 27) at 16 cents per ton, loading 160 tons of clay per 9-hour day.

The transportation or delivery of the material from the workings usually entails considerable expense, though in some places it is a fairly simple matter. If the underground haulage is of considerable length, the use of the mule is favoured. Where the operation is of considerable capacity trains are made up of the full cars outside of the mine for plant or tipple delivery. Where the plant is adjacent to the mine the mule does all the

[1] Reference 99.

transporting with the aid sometimes of a wire-rope haulage system. When the distance to the plant is too great to cover effectively with either the mule or a mechanical haulage system, tipples are used which load into gondolas or motor trucks for plant delivery.

The cars are usually of the low wooden, (Reference 171) end-dump type, as low cars are easier to load by hand. End-dump cars do not require as wide entries as side-dump, and wooden cars are practical when a large number are in use.

In Canada underground mining of clays and shales is carried on in Nova Scotia at Shubenacadie and Musquodoboit; in New Brunswick, in the Minto coal fields (in conjunction with the mining of coal); in Saskatchewan, in the southwestern part where the Whitemud beds occur; in Alberta, at Redcliff; and in British Columbia, at Kilgard.

In New Brunswick, shale of fair quality for the manufacture of brick occurs above and below thin coal seams, and the removal of the shale is incidental to the removal of coal. The roof rock is shale which does not weather readily and makes a fair roof.

Ontario and Quebec abound in clay-winning operations, none of which is underground at present (1934). In the near future underground operations may be resumed at St. Remi d'Amherst, Quebec, where at one time kaolin was mined, and in the refractory clay area of northern Ontario.

A great difference exists in the cost, necessary care, and planning of an underground operation in comparison with a surface operation, and underground mining should be undertaken only when there is no other satisfactory means. For the average shale and clay operation of Quebec and Ontario such a procedure would be unwise, not only because of the added necessary precautions and difficulties but also because of the general quality and distribution of the material in these provinces.

The successful and economical operation of an underground working depends a great deal upon preliminary investigation and planning. Every bit of information possible should be obtained before commencing the workings. The general items of particular value are:—

1. Drill records that would give the lay of the material and its thickness, the nature and depth of the overburden, the nature of the roof and of the floor.
2. Suitable comprehensive tests of the sought material that would show its value.
3. Well mapped property limits that should show all outcrops.
4. The cost of timber.

Reference is here made to "The Mining Laws of Canada" published by the Mines Branch, Department of Mines, Ottawa, Canada, 1931.

TRANSPORTATION

(References 46, 130, 177, 190, 196, 220, 248)

Various means of transportation are utilized in the delivery of clays and shales from the pit to the plant. In Quebec and Ontario the drum-and-wire-rope method is used extensively, alone as well as in conjunction with other means. Locomotives, powered by steam, gasoline, or electricity, are in general use in many plants throughout the continent, the gasoline type being most generally found in the operations of eastern Canada. Aerial transportation is not used extensively but is used in certain localities where its installation is particularly adaptable. The horse and wagon, or horse and cart, are used extensively, and motor trucks are also used to some extent.

Drum and Cable

(References 72, 213, 260)

This system of haulage is flexible and particularly valuable where steep grades and short hauls are encountered. The drums used vary in diameter and the cable is usually seven-eighths of an inch. In places where other means of transportation are used and the dumping point is on a higher level than its delivery point, the drum and cable are usually used to overcome the grade, though elevators are sometimes used at this point.

Lubrication of the wire ropes is very important but it is frequently neglected. Ropes should be regularly lubricated in order to prevent rusting or corrosion and abrasion, reduce internal and external friction, and preserve the inner core. A mineral oil having a viscosity from 200 to 300 seconds at 210° F. is the proper lubricant for ropes of this type. For further remarks on proper lubrication *see* Reference 213.

Locomotives

(References 76, 279, 280)

The steam locomotive has not found very great usage in surface workings of Ontario and Quebec. The advantages of such equipment depend upon moderate grades, long hauls, high daily tonnages, and heavy trips. As the average clay and shale operation is generally concerned with light loads and short hauls over fairly level road beds it has no need for this type of locomotive, which is more expensive than other types and which requires skilled operators.

Gasoline locomotives are the most common type of locomotive found in Ontario and Quebec, and owing to their adaptability and ease of operation they have proved quite satisfactory. They range in size up to 6-ton, those of the lower tonnages being most favoured.

The electric locomotive, necessitating as it does a larger outlay of capital than a gasoline locomotive, has not been so generally accepted. Where they are used, satisfaction with their performance has been expressed.

Brick and Clay Record (June 21/27) quotes the Keystone Mining Catalogue formula for calculating the weight of locomotive to be used:—

$$W = \frac{L\,(R + G)}{20P - G}$$

Where L is the weight of trailing load in tons; the following factors being generally assumed:—

R = 30 pounds for cars from ½ ton to 3 tons;
18 pounds for cars heavier than 3 tons.
P = 20 for cast iron wheels;
25 for steel-tread wheels;
18 for small cars or those equipped with roller bearings.
G = 20 × grade in per cent.

An interesting comparison of tonnages and costs was made in England. (Reference 288.)

	Tons per week	Cost per ton
1. By cart and horse on roads, including cost of fodder for 6 horses, depreciation, interest, repairs, and wages. Distance, 2,436 yards..	220	$0.55
2. By three Fordson tractors on roads, including oil and gasoline, depreciation, interest, repairs, and wages. Distance, 2,436 yards..	380	0.50
3. By one 5-ton steam lorry, end-tipping, including oil and paraffin, depreciation, interest, repairs, and wages. Distance, 2,436 yards..	300	0.32
4. By Fordson locomotive, direct from works to pit, including oil and kerosene, depreciation, interest, repairs, and wages. Distance, 2,766 yards..	262	0.26

Table III shows the preferred transportation equipment for clay and shale workings of various sizes and according to their distance from the plant and relative elevation with regard to plant.

Cars

Cars used to carry clays and shales vary greatly; in the choice of cars the following factors are important: type of loading; daily output; and length of haul.

Material. The steel car is most generally used in the clay and shale workings, as it is rugged and has a fairly long life.

Very seldom in the clay industry does the rolling stock have to withstand the severe punishment that would be experienced in general contracting. This, undoubtedly, is the reason why the steel car has, for the most part, replaced the wooden car which the contractor uses. A clay plant has a limited daily capacity, which in turn eases the work of the machinery. The contractor loads hard and fast, he shunts his cars fast, dumps quickly and returns quickly for the next load. The car which has proved most economical in this work is the wooden box or tray type, principally because of the ease with which it can be repaired. On the other hand, throughout the field of clay-working, the controlling factor is the daily consumption and such procedure as mentioned above is quite unnecessary. The shovel man can afford to take a certain care in loading the cars, the locomotive engineer can take time in shunting and loading and still do the work required. Of course certain operations must be rushed, but they are for the most part not average operations. When such a condition exists the wooden car is used. It is fair to say that the steel car is quite suitable for use in the average clay-working operation.

The wooden car is used where a number of cars are needed, where steep grades are encountered and where loading conditions are such as to be hard on steel cars.

Height. Low cars are used where hand-loading is done since they are easier to load.

TABLE III

Transportation Equipment Suitable for Various Operating Conditions

(Not including aerial transportation)

Distance	Relation	50 to 100 tons	100 to 200 tons	200 to 300 tons	300 to 400 tons	More than 400 tons
One-quarter mile and under	Plant **above** workings.	Drum and cable, animal haulage.	Drum and cable......	Drum and cable*.....	Drum and cable*.....	Drum and cable.*
	Plant **below** workings.	Drum and cable,* plane, animal haulage.	Drum and cable,* plane*.	Drum and cable,* plane*.	Drum and cable,* plane*.	Drum and cable,* plane*.
	Plant **level** workings.	Animal haulage, drum and cable, gasoline or electric locomotive.	Drum and cable, gasoline or electric locomotive.	Drum and cable, gasoline or electric locomotive.	Drum and cable, gasoline or electric locomotive.	Drum and cable, gasoline or electric locomotive.
One-quarter mile to one mile.	Plant **above** workings.	Drum and cable*.....	Drum and cable*.....	Drum and cable and auxiliary equipment.	Drum and cable and auxiliary equipment.†	Drum and cable and auxiliary equipment.†
	Plant **below** workings.	Drum and cable*, plane.*	Drum and cable, plane, auxiliary equipment.†	Drum and cable, plane, auxiliary equipment.†	Drum and cable, plane, auxiliary equipment.†	Drum and cable, plane, auxiliary equipment.†
	Plant **level** workings.	Light gasoline or electric locomotive.	2- to 3-ton gasoline or electric locomotive.	2- to 4-ton gasoline or electric locomotive.	4- to 6-ton gasoline or electric locomotive.	4- to 6-ton gasoline or electric locomotive.
One mile and over.	Hilly country.	4- to 6-ton gasoline or electric locomotive, motor truck.	Steam locomotive, 4- to 6-ton gasoline or electric locomotive, motor truck.	Steam locomotive, 4- to 6-ton gasoline or electric locomotive, motor truck.	Steam locomotive, motor truck.	Steam locomotive, motor truck.
	Level country.	2- to 4-ton gasoline or electric locomotive, motor truck.	2- to 4-ton gasoline or electric locomotive, motor truck.	2- to 4-ton gasoline or electric locomotive, motor truck.	4- to 6-ton gasoline or electric locomotive, steam locomotive, motor truck.	Steam locomotive, motor truck.

*Auxiliary equipment sometimes needed. †Drum and cable usual auxiliary equipment.

Dump. End-dump cars are rarely used on open work. Where one car is hauled by itself to the dumping point, there is little choice of one type over another, but where a train of several cars is hauled, considerable time is saved by the use of side dumpers; with such, the train need not be broken up as is the case with the end dumpers. The bottom-dump car has found very little use in clay-winning operations as it has no distinct advantages over the other types and usually is so designed as to make it unsuitable for machine loading. With machines such as planers, the material being fed slowly to the cars, the use of bottom dumps may be practical.

Capacity. In hand-loading operations, due to the fact that the cars are loaded slowly, a small capacity car has a distinct advantage in that delivery may be made twice as often as with one twice the size. In many operations a frequent delivery is required and when such is the case, under the above conditions the smaller car is more desirable.

Because machine-loading at large capacity plants is gradually replacing hand-loading, the larger car is becoming more essential. Very few shovels used (shovelling being the principal means of loading) have a smaller bucket capacity than three-eighths of a yard. Such being the case a loaded bucket is more easily emptied into a larger car with less chance of spilling, and because of the greater weight with less opportunity for derailing.

In loading small cars with a large shovel it has been found advantageous to load into a chute which in turn would load two cars at once. (Reference 87.)

When large storage space is provided, cars of large capacity can be used profitably, as they can be taken into the plant and dumped where desired. The mill machinery being fed from storage is not likely to be choked by large bulk dumping such as would happen where the material goes directly to a crusher or grinding equipment. When feeding from the car is necessary the large car has to be dumped very slowly in order not to overload the machinery. Where daily tonnages are high it is advisable to use cars of 6-yard capacity, or more, only where machine-loading is used and where ample storage is available.

The medium-sized cars, 2- to 4-yard capacity, are more generally useful in the clay industry because they can be used to advantage either where the material is dumped almost directly into the crusher or where they dump into a storage bin; moreover, they are of such size that they can be loaded by machine.

Rails.[1] In the course of this investigation considerable variance was found not only in the weight of rail but also in the gauge used. The weight of rail varied from 12 to 80 pounds. Brick and Clay Record, June 21, 1927, gave the results of their findings in the United States as follows:

Number of Plants	Weight of rail in pounds
30	16
23	30
11	20
8	60
7	12
6	40
6	35

NOTE.—Other plants reported as using 18, 24, 25, 36, 45, 50, 55, 56, 70, and 90 pounds.

[1] References 76, 236.

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The weight of rail is important because upon it will depend to a great extent the spacing of the ties, the rigidity of the track and the load that can be advisably carried over the track. In Reference 236 will be found much of particular importance to this subject and the following pertinent remarks are taken from it. Where locomotives are used it is inadvisable to use rails lighter than 25 pounds, particularly on permanent tracks since they will not keep in alignment. The data below give the weight of rail advocated for tracks where ties are placed $1\frac{1}{2}$ or 3 feet apart. Rail joints should have the same strength and stiffness as the rails, and the ties should be twice the gauge, at least $\frac{1}{4}$ inch thicker than spike length, and $1\frac{3}{8}$ times the spike length in width. The gauge should not be less than half the extreme width of the car or locomotive and should be slightly wider on curves. The life of the ties will vary, all other things being equal, with the wood used, the long-life woods being chestnut, white oak, and cypress. Other woods such as hemlock and white pine average about 5 years.

Permanent and semi-permanent lines should be laid well and be made up of heavier rail, good ties, good joints, and planned curves. Temporary tracks can, for convenience, be made of lighter rails and do not require the initial attention of the other types.

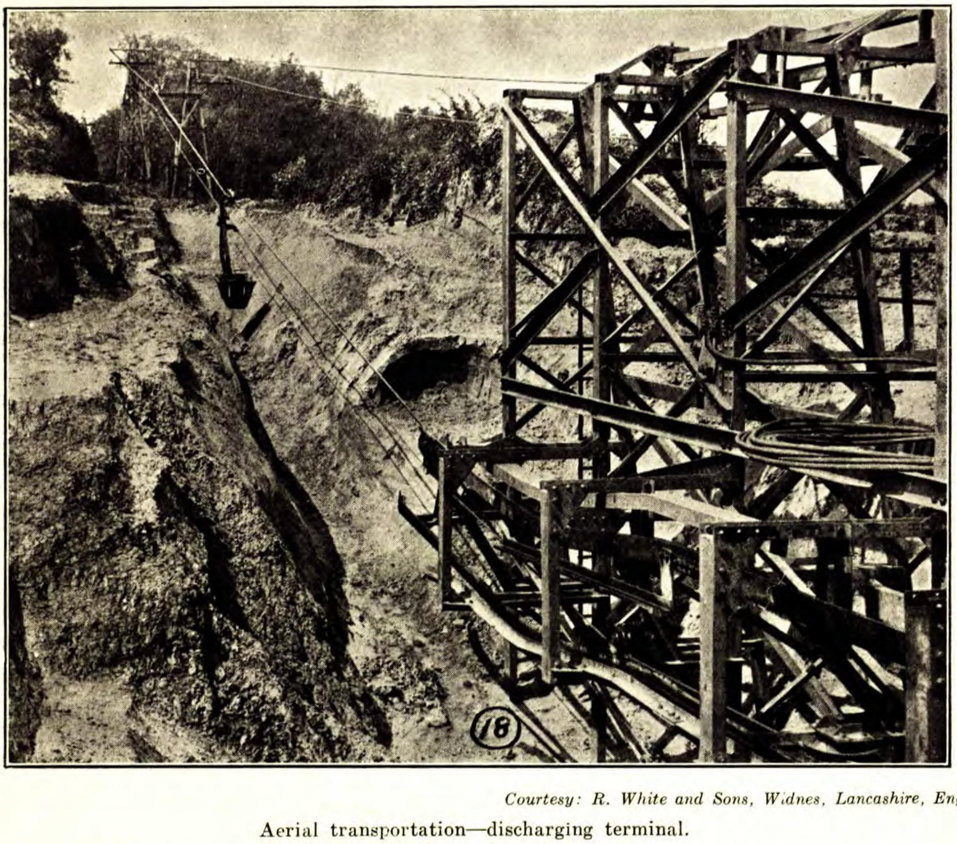
The American Society of Civil Engineers recommends the following weight of rails:—

Maximum single wheel load	Safe weight of rail for maximum wheel load, lb. per yard	
	Ties, 18-inch centre	Ties, 36-inch centre
500	12	12
1,000	12	16
1,500	12	20
2,000	20	25
2,500	20	30
3,000	25	30
3,500	27	35
4,000	30	40

Aerial Transportation

This method of transportation has been developed considerably during the present century and is successfully used in many types of material-handling operations. In the clay industry on this continent, however, it has not been so well received as it has in England. Whether the initial cost has been the reason for its not being more widely adopted is not known. There are, however, places where this type of haulage equipment properly belongs, and the following notes are given to point out its outstanding features and what extreme conditions it can meet.

PLATE XVII



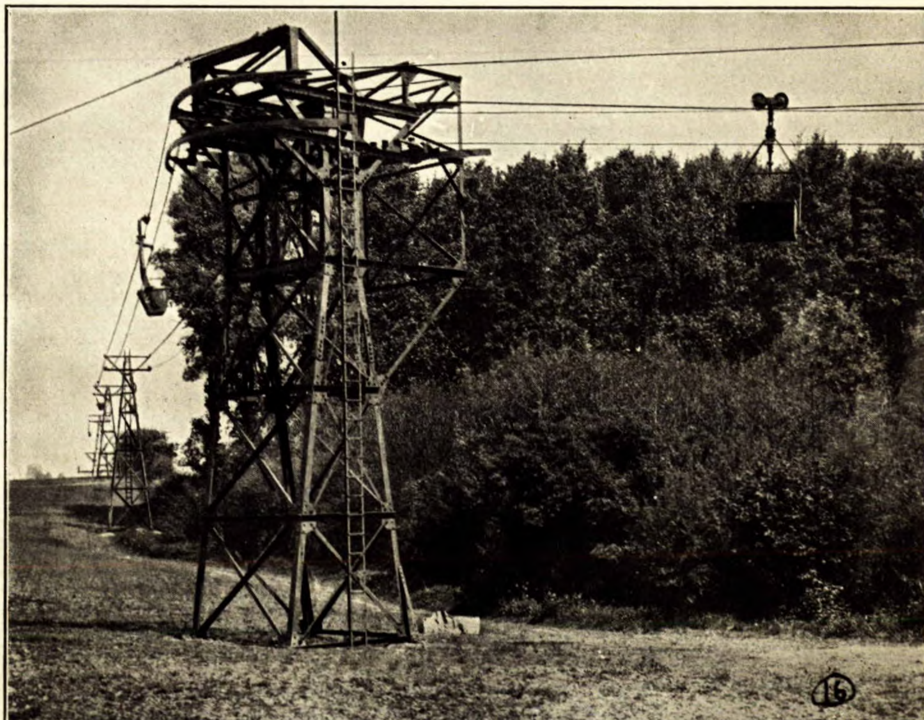
Courtesy: R. White and Sons, Widnes, Lancashire, Eng.

Aerial transportation—discharging terminal.

Aerial transportation (References 13, 14, 46, 84, 288) is recommended when loaded buckets will have down grade, as an economical delivery system over long distances, and when difficult transportation problems are encountered, or when a change in position is not contemplated.

Plates XVII and XVIII show two views of one of the more recent wire-haulage systems put into service in a clay operation in England. This is part of a system one mile long. There are in this layout 15 such towers as shown in Plate XVIII, besides 6 loading and discharging terminals (Plate XVII) and 3 angle stations (foreground of Plate XVIII), and 2 road crossings. The towers are placed at from 80 to 359 feet apart,

PLATE XVIII



Courtesy: R. White and Sons, Widnes, Lancashire, Eng.

Aerial transportation—angle tower.

depending upon the nature of the country and layout features. This system has been worked successfully and economically in:—

1. Carrying clay to weathering sheds from pit.
2. Carrying clay from weathering pit to plant.
3. Carrying sand to storage from pit.
4. Carrying sand from storage to plant.

Other Types

Motor trucks (References 157, 165) and trailers have been used to advantage where the clay plant and workings are separated by a mile or more and where good roads are available.

Horse and wagon haulage is applied where distances are short, labour cheap, and daily tonnages small.

Hand-pushed cars are utilized (one-quarter yard) in one operation where distance is approximately 50 yards (Plate XIX).

A system described in Reference 87 has proved quite economical and efficient. It consists of a train of automatic dumping cars connected by endless wire rope which is in continuous movement and which is loaded from hoppers. Its description is given operating over a haulage distance of $1\frac{1}{4}$ miles.

PLATE XIX

Hand-pushed cars.

COSTS

In the workings studied, digging and blasting costs varied from 90 to 80 per cent of the total winning costs, the lower costs being at those workings where the output was below 80 tons per day, transportation charges making up the difference. In operations where daily tonnages were greater (up to 360 tons) the digging charges dropped to between 50 and 60 per cent of the total charges and the transportation costs made up the difference.

Wages of Labour

In workings visited by the writer in 1927, 1928, and 1929, the following bases were used for payment of wages.

1. Per hour.
2. Per load of material delivered.
3. Per thousand brick produced by plant.

The first was by far the most generally used basis, and too few plants were working on Nos. 2 and 3 to form any direct comparison as to advantages of one over another.

TABLE IV

Labour Wages

	Basis	Low rate	High rate	Average	No. of plants
Drillers..	Hour	0·30	0·50	0·40	6
Stone pickers..	"	0·30	0·45	0·40	5
Shovel operators..	"	0·35	0·67	0·50	14
Shovel firemen..	"	0·275	0·475	0·361	7
Drum operators..	"	0·27	0·475	0·358	7
Horse drivers..	"	0·30	0·45	0·32	8
Diggers and loaders.. .. .	"	0·27	0·45	0·337	10
" "	M. brick	0·20	0·24	0·22	2
Watchmen..	Day	3·00	3·50	3·25	2
Brake and switchmen.. ..	Hour	0·29	0·35	0·317	4
Unloaders..	"	0·30	0·35	0·325	3
Locomotive operators.. ..	"	0·325	0·40	0·341	3
Truck drivers..	"			0·45	1

Labour charges were placed as follows:

Drilling and Blasting. Labour charges represented from 22 to 72 per cent of the total cost, averaging 44 per cent.

Digging and Loading. Labour charges represented from 26 to 98 per cent of the total digging and loading charges, averaging approximately 64 per cent.

Transportation. Labour charges represented from 29 to 89 per cent of the total transportation charges.

Steam Shovels

Labour charges for the operation of a steam shovel approximated 5 cents per ton of material and the cost of fuel and lubricants increased with daily tonnages, approximating 2 cents per ton of material. The labour charges per ton not decreasing with increased daily tonnages seems peculiar, but it must be remembered that in a clay working the amount of labour required on a steam shovel increases with the increase in daily tonnage.

Drum and Cable Haulages

The highest cost for transportation in this manner approximated 15 cents per ton (very high), while the lowest was 2 cents per ton (low). The bulk of operations approximated 5 cents per ton over a distance varying from 50 to 200 yards.

Horse and Wagon Haulage

This type of haulage was found to approximate 14 cents a ton when the haulage distance was approximately 300 yards, and 10 cents per ton when the haulage distance was 100 yards. The use of horse-drawn cars on tracks cut down delivery costs considerably; the average cost when haulage distance was 200 yards, being approximately 6 cents per ton, while with a distance of 750 yards the cost was 11 cents per ton.

Locomotive Haulage

There was no relationship found to exist between the cost per ton and the distance hauled, nor were there a sufficient number of plants visited to make any direct statement concerning it. It was found, however, to be higher than drum and cable haulage, under 300 yards, and in one instance to approximate 7 cents per ton over a distance of 700 yards.

Truck Haulage

In the one operation studied where motor trucks were used, the transportation costs were found to be 13 cents per ton over a distance of 500 yards, but this was not an ideal place for the use of motor trucks.

Blasting

The figures showed that the cost of blasting varied from 3·8 to 9·4 cents per ton of shale, and approximated 1 cent per ton of clay.

These costs represented from 10 to 35 per cent of the winning costs and were distributed as follows:—

With daily tonnages of less than 50, the labour charges were from 30 to 70 per cent of the blasting costs. The equipment charges approximated 15 per cent of the blasting costs, there being no marked difference existing in increased tonnages. The material charges increased directly with daily tonnages and represented from 30 to 60 per cent of the costs, whereas labour charges remained below 50 per cent.

The charges for dynamite and caps, etc., in shale operations varied from 1 to 7 cents per ton of shale, while they varied from 1 to 2 cents per ton of clay.

The presence of stone in the shale beds increased the cost of blasting.

Overburden

The cost of removal of overburden was found to vary from 2 to 25 cents per ton of desired material. The figures showed that the costs of the removal of overburden are in direct relation to the depth removed, and approximate 1·2 cents per foot per ton of desired material.

Overburden removal represented from 2 to 30 per cent of the winning costs.

CHAPTER III

OPERATIONS AND COSTS AT WORKINGS STUDIED

Following are descriptions and costs of forty-three clay-gathering workings in Ontario and Quebec.

Eight small plants were visited in southwestern Ontario and because of their similarity these are grouped together.

Workings Nos. 1 to 8

The clay, which is a fine-grained, slightly calcareous material containing stones (some of which are boulders), burns to a fair red colour. It lies in beds of from 12 to 48 inches in depth underneath a varying thickness of black loam.

Stripping. The black soil which covers the clay to a depth of only a few inches is a high-shrinking material and when present in the ware tends to cause cracking and warping. Stripping is not necessary at the plants where the depth of clay is 30 inches or more, or where the digging is done by machinery, since the amount of overburden is a small and fairly constant percentage of the total. On the other hand, where the clay is less than 30 inches the percentage of black soil is too high to allow its use. Moreover, where the clay is dug by hand, stripping is practised as the men find the soil much easier to dig than the clay and frequently throw in too much if the clay has not been stripped. Stripping is done by ploughing a furrow and removing the soil by hand shovels or scrapers, sufficient being removed at one time to allow for a month's or six weeks' working.

Removal of Clay. At four plants the clay was dug by hand, and at four, by a shovel carrying a $\frac{3}{8}$-yard bucket. One was operated by a 4-cylinder engine equipped for burning natural gas; one, by a 1-cylinder gasoline engine; one, by a 4-cylinder gasoline engine; and the fourth, by an electric motor. In two of the hand plants, two men dug; in the other two, three men were employed in the digging and loading.

Transportation. The clay was carried in cars on rails over distances varying up to one-half mile. The cars were pulled by home-made locomotives, or by horses. The gauge of rail varied from 20 to 36 inches and the weight from 12 to 30 pounds per yard. Due to the flatness of the country the only grade was that which entered directly to the plant. Hoisting drums were used to overcome this grade at all plants but one, in which an elevator was provided for carrying the clay to a point above the plant machinery.

Car Equipment. No standard type of car was used (excepting that they were all side-dump). They varied in capacity, shape, and the material of which they were made.

Storage. No provision for storage was made at any plant, the clay going directly from the car to the machine.

Removal of Stone. Only one plant provided any special mechanical means for the removal of stone. This was a roller arrangement which crushed the clay, but rejected the stones; by means of a mechanical arm that worked back and forth between the two rolls, the stones were removed. Usually the men loading the cars were depended upon to rid the material of the stone. At one plant a man stood on top of the car, and as the machine loaded the clay into it, he worked the clay over with a fork and threw the stones out.

Drainage. Due to the flatness of the country, digging is hampered by rains and standing water, and at all the pits certain drainage arrangements are necessary. In most cases either tiled or open drains are used. In some pits it is necessary to advance the ditch with the working, as only in extremely dry weather are the workings entirely free of water.

At every plant the clay for 25 to 50 feet ahead of the digging was kept in a moist condition by the addition of water; in some cases to such an extent as not to require further water for the manufacture of the ware. The water for this purpose was obtained either by piping out to the excavation, or by hauling in tank cars, or from the draining of the property.

Winter. Before closing down for the winter months, straw is placed over the clay bed at such places where the spring operations will commence. This allows easy working in the early spring by preventing the deep penetration of frost.

Cost of Operation per Ton of Clay

Plant No.	Daily tonnage	Digging			Haulage			Cost per ton
		Labour	Equipment	Material	Labour	Equipment	Material	
		$	$	$	$	$	$	$
1..........	30	0·117	0·025	0·043	0·109	0·027	0·077	0·398
2..........	30	0·117	0·025	0·040	0·109	0·027	0·043	0·361
3..........	28	0·125	0·027	0·042	0·116	0·051	....	0·361
4..........	20	0·300	....	....	0·150	0·120	....	0·570
5..........	39	0·090	0·019	0·013	0·077	0·049	....	0·248
6..........	35	0·257	....	....	0·086	0·050	....	0·393
7..........	35	0·229	....	....	0·114	0·056	0·016	0·415
8..........	20	0·400	....	....	0·200	0·086	....	0·686

Workings No. 9

The plant is at a much higher elevation than the pit and is 2,300 feet from it. The clay, which is quite sandy and easily dug, is in a bed 4 feet in thickness, and rests on silt. It is covered with 6 inches of a high-shrinkage loam that has to be removed. As the pit is in the lowlands it is not easily drained and shut-downs are frequent because of water. No provision is made for storing the clay. The average daily output from the pit is 90 tons, all of which is used in the manufacture of soft-mud brick. The clay is dug by hand and loaded into steel side-dump cars, drawn by horses to the base of an incline, up which the loaded cars are drawn by a drum and cable run off the main shafting of the plant. The man in charge of the brick machine also operates the drum which draws the clay up. The pit crew is composed of five diggers and one man who takes charge of the two horses and the haulage to the base of the incline.

Overburden is removed by the pit crew every six weeks. The plant is operated on an average of 7½ months in the year.

Cost per Ton of Clay

Overburden		
Labour	$0·009	$0·009
Digging and Loading		
Labour	0·179	0·179
Haulage		
Labour	0·099	
Equipment	0·012	
		0·111
Total		$0·299

Workings No. 10

The plant is located at an elevation of 25 feet above the clay bed and very close to it (350 feet). There is no overburden but the clay is somewhat tough for hand-digging and requires watering down. The bed, which consists of two clays—upper and lower—has an average thickness of 5 feet and is quite free from stones. The upper clay burns to a much deeper red than the lower one. Both are worked at the same time by two diggers, one digging the upper bed, the other the lower one, and both loading the same car. The pit is naturally drained, and it is only in very wet weather that water becomes troublesome. The clay is hauled by means of a drum and a cable working off the main shaft of the plant. The plant is operated on an average of 7 months in the year and the daily consumption of clay is 30 tons, all of which is used in the manufacture of drain tile.

Cost per Ton of Clay

Digging and Loading		
Labour	$0·266	$0·266
Haulage		
Labour	0·005	
Equipment	0·005	
		0·010
Total		$0·276

Workings No. 11

Owing to the manner in which the operations were conducted accurate cost figures could not be taken.

The clay lies in a 7-foot bed and is very tough, dynamite being used to loosen it. It is then shovelled by hand into a horse-drawn dump cart. The pit, which is 250 feet from the brick plant, is poorly drained and is worked only intermittently.

Workings No. 12

The clay bed has a thickness up to 20 feet, but at present only the top 8 feet is being worked. No appreciable overburden is present. The dumping point is located about 25 feet above the pit bottom. In the morning, clay sufficient for the afternoon's run is loosened by a team and small scoop shovel and piled at a place convenient for loading on cars. In the afternoon, two men shovel the clay into cars which are drawn out of the pit to a point above the clay machine by a drum operated from the main shaft. The plant operates on an average of 6 months in a year and uses 12½ tons of clay per day. The drainage of the pit being naturally poor, a gasoline-driven pump is run all day, except in very dry weather.

Cost per Ton of Clay

Digging and Loading		
Labour	$0·320	
Equipment	0·010	
		$0·330
Haulage		
Labour	0·012	
Equipment	0·010	
		0·022
Drainage	0·005	0·005
Total		$0·357

Workings No. 13

The plant, which consists merely of a soft-mud brick machine, is located very close to and at a slightly higher elevation than the clay pit. The clay, which is fairly tough and free from stones, has an average thickness of 8 feet. Digging is done by one man operating a tractor, which draws a scraper of one-half yard capacity. The clay is dug on the down grade, to a point about 6 feet below the dumping point and within 30 feet of it. The tractor turns about and climbs back with the load to the dumping point, travelling about 300 feet. During wet seasons traction becomes rather difficult, but, as a rule, drainage is not a serious problem due to the slope from which the clay is taken. The plant operates on an average of 4 months in a year, using 50 tons of clay per day. Stripping is done once a year, before work commences.

Cost per Ton of Clay

Overburden		
Labour	$0·008	$0·008
Digging, Loading, and Hauling		
Labour	0·158	
Material	0·024	
		0·182
Total		**$0·190**

Workings No. 14

The clay bed, which is located at a higher elevation than the clay-working machinery, consists of a fairly tough upper clay, which contains a few stones, and a sandy lower clay. Both beds are worked together and in equal quantities. The overburden, which is 6 inches thick, is removed by hand twice a year. The clays are kept well-watered to promote ease of hand-digging. The clay is loaded by hand into horse-drawn carts, and is transported to the plant about a quarter of a mile distant. Wet weather makes hard going for the horses over a clay road to the plant, but, because of the natural drainage, causes no particular trouble in the pit. The plant operates on an average of 6 months a year, using 50 tons of clay daily in the manufacture of soft-mud and stiff-mud brick.

Cost per Ton of Clay

Overburden		
Labour	$0·017	
		$0·017
Digging and Loading		
Labour	0·225	
		0·225
Haulage		
Labour	0·082	
Equipment	0·003	
		0·085
Total		$0·327

Workings No. 15

The plant is located in level country. The clay, which is a surface one, lying in a bed averaging $2\frac{1}{2}$ feet in thickness under 6 inches of loamy overburden, is dug and loaded into dump carts by hand. Some transportation trouble is met with during rainy weather, but as the pit is drained by a ditch, the more common difficulty is lack of moisture in the clay.

The plant is located 1,000 feet from the clay operation and the dumping point is about 10 feet above the ground level; this grade is overcome in 75 feet. The plant operates on an average of 6 months in the year, and consumes 40 tons of clay daily in the manufacture of hollow ware and building brick. There is a 6-inch layer of high-shrinkage loam over the clay bed, which is removed as the digging progresses.

Cost per Ton of Clay

Digging, Loading, and Haulage		
Labour	$0·162	
		$0·162
Haulage		
Horses	0·054	
Equipment	0·006	
		0·060
Total		$0·222

Workings No. 16

This working is located in level country. The clay lies in a bed averaging 2 feet in thickness underneath a 6-inch covering of high-shrinkage loam that is removed as the digging progresses. The material is quite easily dug by hand shovel. The working is located about 1,400 feet from the dumping point. There are no grades or other natural hindrances between the loading place and the dumping place, and haulage is done by horse-drawn dump wagons. The working is naturally drained and offers no trouble except in extremely wet weather. The clay is dumped into a bin to be soaked, from which it is shovelled by hand into the clay machine. The plant operates on an average of 6 months in the year and uses 43 tons of clay per day in the manufacture of hollow ware and building brick.

Cost per Ton of Clay

Digging and Loading		
Labour	$0·163	
		$0·163
Haulage		
Labour	0·139	
Equipment	0·007	
		0·146
Re-shovelling		
Labour	0·146	
		0·146
Total		$0·455

Workings No. 17

This is a shale operation. The shale lies in a bank 75 feet in thickness and is covered with a 6-inch overburden which is used with the shale. The face worked is about 100 yards wide and the working has been extended 70 feet into the bank. The shale is blasted with dynamite and shovelled by hand into cars, which when full are pushed by the digger to the plant for a distance varying from 75 to 150 feet. A crew of four men, including the foreman, who takes charge of the blasting, delivers an average of 58 tons of shale per day to the plant. A compressed-air drill is used for drilling. A drainage system has been installed under the present working level to ensure good working in wet weather. The plant is located at the base of the bank, and practically next to it. The plant operates on an average of 172 days in the year. No provision is made for storage.

Cost per Ton of Shale

Blasting, Loading, and Haulage		
Labour	$0·331	
Equipment	0·026	
		$0·357
Drainage	0·001	
		0·001
Total		$0·358

Workings No. 18

This is a shale operation. The shale is in a bank up to the height of 70 feet covered with 3 feet of overburden which is removed by hand before blasting. The shale is blasted loose and loaded by hand into horse-drawn dump carts that carry it 100 yards to the dumping point. The face of the bank worked is about 200 yards wide. The plant is located on a lower level than the digging operation and haulage is not difficult. Drainage is provided by a gentle slope in the base of the workings. The plant operates on an average of 260 days in the year, consuming 55 tons daily in the manufacture of dry-press brick.

Cost per Ton of Shale

Overburden		
Labour	$0·029	
		$0·029
Blasting and Loading		
Labour and material	0·307	
		0·307
Haulage		
Labour	0·117	
Equipment	0·002	
		0·119
Total		$0·455

Workings No. 19

The plant is located at the base of a hill from which the clay is obtained. The drop from the present clay workings to the dumping point at the plant is 40 feet. The clay has been worked out in benches stepped back for a distance of 575 feet. The clay, which is dug by hand, is tough and requires watering down. Forty tons of clay are won daily for the production of soft-mud brick. The face worked is 6 feet deep by 30 feet wide. The 1-foot bed of overburden is removed by hand. The clay is shovelled by hand into horse-drawn dump carts which carry it to the plant. In wet weather transportation is difficult on the clay road. Drainage is natural and good.

Cost per Ton of Clay

Overburden		
Labour	$0·060	
		$0·060
Digging and Loading		
Labour	0·291	
		0·291
Haulage		
Labour	0·060	
Equipment	0·013	
		0·073
Total		$0·424

Workings No. 20

This pit is operated by a contractor who loads the clay into railroad cars for 45 cents per ton. The company furnishes him with a steam shovel, together with the necessary fuel and oil. The operation is a surface one; the clay has an average depth of 2 feet and is easy to dig. Below the clay is a very limy clay which, when mixed with the top clay, produces considerable trouble in the finished ware. Although the country is quite hilly and drains fairly well, heavy rains make the operation a very difficult one; not only is working inconvenient but excessively wet clay is very undesirable for the manufacture of the product. From the present digging to the dumping point is approximately a quarter of a mile. The hauling is done by teams in bottom-dump carts of 2-yard capacity, which are furnished by the contractor. Five teams are usually employed. The company has a large storage bin in which the supply of clay for the winter and early spring is stored.

The daily production is 99 tons.

Cost per Ton of Clay

Digging, Loading, and Haulage	
Contract	$0·450
Equipment	0·085
Material	0·043
Total	0·578

Workings No. 21

Deposit. This is a surface deposit of clay located in slightly rolling country.

Output. Sufficient clay is moved for the manufacture of 24,000 soft-mud brick per day for an average of 50 days per year.

Method of Winning. The clay deposit has been uncovered to an extent of some 5,000 square yards. This exposure permits of a certain amount of weathering which facilitates ploughing and harrowing. A portion of this exposed area, having been broken by a tractor-drawn plough and harrow, is traversed by a horse-drawn clay gatherer which with its rotating shovels loads the loosened clay into its drum. A carload having been collected in the drum it is drawn to the loading trap and dumped into a waiting car.

Haulage. The car is then pulled by cable to the brick plant where the clay is dumped directly into the brick machine. The haulage distance is 200 yards, part of which consists of a climb of 25 feet to the dumping point at the plant.

Comment. The system which provides a large area for evaporation has a distinct advantage for the operation of clay deposits which have a tendency to hold such a high percentage of moisture as to make the clay too wet for use in the brick machine.

This system adequately supplies the need of the plant, except in wet weather when travel is particularly hard for the horses and when the clay is sticky both in situ and in the drum of the gatherer. Reserve storage would be highly desirable in an operation of this type.

Cost per Ton of Clay

Digging		
Labour	$0·157	
Equipment	0·049	
		$0·206
Haulage		
Labour	0·024	
Equipment	0·035	
		0·059
Total		$0·265

Workings No. 22

This working and No. 23 are worked together, furnishing a plant with shale and clay respectively for the manufacture of hollow building tile.

Deposit. A pit, 50 feet by 400 feet, has been opened to a depth of 25 feet into hard, grey shale. The shale lies to an undetermined depth under the present working-floor. The immediate countryside wherein this pit is located is quite hilly.

Output. An average of 100 tons of shale is removed daily.

Winning. A compressed-air drill is used for boring holes into the shale, dynamite being used to blast the shale loose. Six men make up the pit crew that loads the shale into cars by hand.

The pit crew consists of 9 men, 6 are employed in blasting and loading and are paid "en masse" per ton loaded, the other three take care of transportation and are paid by the hour.

The plant operates year round on a 10-hour day, and maintains a comparatively good system of cost-keeping.

Haulage. The shale is loaded into steel, side-dump cars (of which there are six), each of 2-yard capacity. When loaded the cars are hitched separately to a cable which winds about an electrically-operated drum and hauls them out of the pit, a distance of 190 yards. The cars are then hauled, three at a time, by gasoline locomotive to the plant 300 yards distant.

The track is kept in good condition and the locomotive has no trouble taking the load up the slight grade between the pit and the plant.

Drainage. In heavy rains it would be difficult to operate the pit if it were not for some drainage system. A deep sump, to which the pit drains, serves to keep the pit workable.

Cost Per Ton of Shale

The following figures have been calculated on a 300-day year and a 100-ton daily output.

Quarrying, Labour (absorbed by loaders)		
Equipment	$0·021	
Material	0·034	
		$0·055
Digging and Loading		
Labour	0·320	
Equipment	0·006	
		0·326
Haulage		
Labour	0·123	
Equipment	0·076	
Material	0·005	
		0·204
General		
Equipment	0·003	
		0·003
Total		$0·588

Workings No. 23

Nature of Deposit. This is a Pleistocene clay deposit which underlies a slight depth of loamy soil (6 inches to 1 foot). The clay is free of stone and has been dug to a depth of 4½ feet. The face exposed shows no bedding of sand or silt. The clay lies to an undetermined depth below the present working.

Output. This operation provides an average of 200 tons of clay per day which is used in the manufacture of building tile. The operation is worked year round on a 10-hour day.

Overburden. The overburden is removed by one man who keeps ahead of the working, shovelling the loam into the old working.

Winning. The clay is dug and loaded by a side-wheel ditcher, the rotating bucket knives cutting the clay, catching it, and dumping it onto a belt which delivers it to waiting cars.

Haulage. The operation is provided with 6 steel, side-dump cars of 2-yard capacity. The loaded cars, three to a trip, are hauled by a 3-ton gasoline locomotive from the operation to the plant, a haul of 700 yards.

Storage. Provision is made for storage as on severe wintry days and in the early spring the efficiency of the bank operation is greatly impaired. At such times the reserve storage is drawn upon to keep the plant operating at average capacity.

Cost per Ton of Clay

Overburden		
Labour	$0·017	
		$0·017
Digging and Loading		
Labour	0·034	
Equipment	0·021	
Material	0·009	
		0·064
Haulage		
Labour	0·044	
Equipment	0·024	
Material	0·002	
		0·070
Total		$0·151

Workings No. 24

Nature of Deposit. This is a hard shale interstratified with limestone The depth of the bed worked is 75 feet. The limestone strata, varying in thickness from 2 to 5 inches, make up approximately 50 per cent of the face. This limestone adds considerably to the cost of winning the shale and must be removed before the shale goes to the plant, since no removal is feasible at the machines.

Overburden. Over this shale deposit lies a 21-foot bed of sand, the removal of which is dealt with under Workings No. 26, page 63.

Output of Shale. On an average, 125 tons of shale per day is removed from this pit, which is 1,000 feet long, 500 feet wide, and 75 feet deep. The shale is used in the manufacture of stiff-mud building brick and hollow building tile.

Winning. The shale is worked in benches, from the top in a series of 10-foot steps toward the bottom of the pit. A good deal of shale is blasted loose during the course of a year and this shale is allowed to weather, first, to permit the development of more plasticity, and second, to facilitate the separation of the limestone from the shale. This weathering is allowed to go on for two years usually, but occasionally it becomes necessary to use the shale much sooner. The shale is loaded by a steam shovel into cars.

Separation of Stone. Much of the stone is separated by the drilling crew as the benches are being prepared for drilling and blasting; moreover, when blasted loose from such a height, a great deal of the shale is shattered free of the limestone. After weathering, the stone is picked by hand from the shale and loaded into cars.

The stone can sometimes be sold for building purposes and sometimes for road material, but there is not a steady market for the material. The stone not sold is usually dumped along the incline to the plant, or used for filling in those parts of the pit from which the shale has been removed.

Haulage of Shale. The loaded cars are pushed by hand to the base of an incline and hauled by cable to the plant where the cars are dumped by hand into a small bin from which the shale goes directly to the dry pans.

Drainage. Drainage is accomplished by means of small ditches which lead to a well from which the water is pumped free of the pit by a pulsometer.

Storage. No provision is made for storage.

Comment. As can readily be seen this is a rather difficult operation to carry on cheaply. The pit has three high, perpendicular faces. The material probably could be worked more economically as a series of benches, but it is difficult to see where radical improvements can be made. However, the large face of the pit is advantageous in that the shale weathers to a great extent due to exposure at the pit faces, but from a mining standpoint it is a drawback as winning is made so much more difficult.

Cost per Ton of Shale

Drilling and Blasting		
Labour	$0·119	
Supervision	0·014	
Equipment	0·012	
Material	0·041	
		$0·186
Separating and Loading		
Supervision	0·014	
Labour	0·135	
Equipment	0·069	
Material	0·025	
		0·243

		$0·429
Haulage		
Supervision..	$0·014	
Labour..	0·089	
Equipment..	0·037	
Material..	0·009	
		0·149
General		
Equipment..	0·006	
		0·006
Total..		$0·584

Workings No. 25

The deposit is a sand and boulder clay bed directly overlying the shale described in Workings No. 24. The bed in cross-section shows 3 feet of sand, followed by alternating layers of gravel and sand down to a 3-foot bed of boulder clay at the base, 21 feet in all.

Although some of the sand is used in manufacture, most of it is discarded along with the boulder clay.

The material is blasted free of the bank, loaded by hand into drop-bottom wagons and hauled to a dumping place 500 yards distant.

The figures given are in cost per ton of shale removed (Workings No. 24) and in reality represent the cost of removal of overburden for that operation.

Drainage is natural.

Cost per Ton of Shale

Supervision..	$0·011	
		$0·011
Quarrying		
Labour..	0·004	
Material..	0·007	
		0·011
Digging and Loading		
Labour..	0·130	
Equipment..	0·002	
		0·132
Haulage		
Labour..	0·065	
Equipment..	0·038	
		0·103
Total..		$0·257

Workings No. 26

Nature of Deposit. A section of the deposit shows 6 feet of sand and gravel overlying 70 feet of clay. The clay section grades from a very sandy clay at the top to a fat clay at the base.

Output. This operation provides an average of 80 tons of clay per day for use in the manufacture of soft-mud and stiff-mud brick.

Overburden. The 6 feet of sand and gravel is removed by an electrically-driven dredge. Three days' stripping is sufficient for the removal of overburden for a year's supply of clay.

Winning. The clay is blasted loose from the bank and loaded by hand into cars.

Haulage. Four wooden, side-dump cars, holding $1\frac{1}{2}$ yards, are used to transport the clay. The loaded cars are attached to a $\frac{5}{8}$-inch steel cable and hauled by electric hoist up an incline to the plant, a haul of 230 yards with an 85-foot rise.

Storage. Storage is provided for a 2-day run without operation of the pit.

Drainage. A sump, 25 feet below the working-floor of the pit, provides drainage. An electrically-driven pump lifts the water free of the pit. However, in wet weather, the working of the pit is very difficult.

Cost per Ton of Clay

Overburden		
Labour	$0·003	
Equipment	0·023	
		$0·026
Winning		
Labour	0·270	
Equipment	0·007	
Material	0·010	
		0·287
Haulage		
Labour	0·017	
Equipment	0·021	
		0·038
General		
Equipment	0·004	
Power	0·003	
		0·007
Total		$0·358

Workings No. 27

Nature of Deposit. A face, 65 feet in height, shows a cross-section of 8 feet of very sandy loam underlain by a soft clay, the sand content of which decreases as the base of the deposit is approached.

Output. This operation provides 85 tons of material per day, which is used in the manufacture of a good grade of soft-mud brick. The operation is worked 9 hours per day for 9 months of the year.

Winning. The loam is dug and mixed with the sandy clay and the fat clay in the manufacture of brick. The clay is blasted loose from the bank and loaded by hand into wooden, side-dump cars.

Haulage. The loaded cars are carried by gravity for 50 feet in the direction of the plant. A horse then draws them 150 feet to a switch at the base of an incline, where a cable is attached and the cars are drawn by electric hoist up the grade (75 feet in 300 feet) to the plant. The clay is dumped into the brick machine as fast as the machine will take it. When empty, the cars are lowered to the pit.

Storage. No storage space is provided.

Drainage. In wet weather the water drains to a sump from which a pump elevates it to the city sewer.

Cost per Ton of Clay

Digging and Loading		
Labour	$ 0·169	
Equipment	0·007	
Material	0·023	
		$ 0·199
Haulage		
Labour	0·093	
Equipment	0·026	
Power	0·014	
		0·133
General		
Equipment	0·006	
		0·006
Total		$ 0·338

Workings No. 29

Nature of Deposit. At the time the data here presented were obtained a pit, 100 feet wide and 200 feet long with a 20-foot face, had been opened up. The material is a grey, hard shale interstratified with limestone. There is no overburden, the country about is very level.

Output. An average of 120 tons of shale per day is used in the manufacture of common and face brick.

Winning. The shale and stone are blasted loose from the bank, sorted, and loaded by hand into cars. The blasting is done by contract at $10 per hole, which furnishes sufficient material for 175,000 brick.

Haulage. The shale is carried in 1-yard, steel side-dump cars, the cars being pushed by hand to the base of an incline (a distance varying from 40 to 50 yards) and then attached to a cable electrically operated, and hauled up the incline to the plant.

Storage. There being no provision for storage the shale is dumped direct into a hopper feeding the dry pans.

Cost per Ton of Shale

Drilling and Blasting		
Labour	$ 0·017	
Material	0·051	
		$ 0·068
Sorting and Loading		
Labour	0·350	
Equipment	0·025	
		0·375
Haulage		
Labour	0·033	
Equipment	0·008	
Power	0·002	
		0·043
General		
Equipment	0·002	
Power	0·001	
		0·003
Total		$0·489

Workings No. 30

Nature of Deposit. A 15-foot bed of buff-burning, hard shale underlying a 6-foot bed of clay is worked. The shale contains some limestone which must be removed.

Output. The operation provides sufficient material for the daily manufacture of 17,000 dry-press brick. It is operated 10 hours a day for 8 months in the year.

Overburden. Two feet of the clay is used in the manufacture of drain tile, the remaining 4 feet being discarded. The work of one man is sufficient for removing the overburden.

Winning. The shale is blasted free, the limestone separated by hand from the shale, and each is loaded by hand into separate cars.

Haulage. The full cars are pushed from the loading place to a point nearby, a distance of from 10 to 100 feet, where a cable is attached, and the car hauled by electric hoist approximately 100 yards to the plant.

Drainage. No special provision is made for drainage, the pit some days being quite unworkable but not frequently so.

Storage. No provision is made for storage.

Cost per Ton of Shale

Supervision		$ 0·070
Overburden		0·060
Drilling and Blasting		
Labour	$ 0·120	
Material	0·068	
		0·188
Loading		
Labour	0·180	
Equipment	0·009	
		0·189
Haulage		
Labour	0·030	
Equipment	0·018	
Power	0·008	
		0·056
Total		$ 0·563

Workings No. 32

Nature of Deposit. Shale is exposed to a depth of 40 feet underlying a clay overburden which is seen to increase as the workings penetrate the bank. The overburden averages 10 feet in depth and is not used. The top 30 feet of shale is red-burning, while the lower 10 feet is buff-burning. The shale is free from any appreciable amount of stone.

Output. From this operation 350 tons of shale are taken per day for the manufacture of building brick by the stiff-mud and dry-press processes. Two plants operating 10 hours per day for 10 months of the year are supplied from this one deposit.

Winning. In order to operate this face so as to keep the overburden, the red-burning shale, and the buff-burning shale separate from one another, it has been found expedient to work the face on three levels.

The materials are dynamited loose and loaded by power shovel (there being one on each level) into motor trucks.

Haulage. The motor trucks haul the shale from the bank to the plant a distance of 500 yards.

Overburden. The clay which overlies the desired shale workings is removed in a similar manner to the shale. Three months' work on the removal of overburden suffices for a year's operation on the shale.

Cost per Ton of Shale

Overburden		
Labour	$ 0·026	
Equipment	0·034	
Material	0·008	
		$ 0·068
Drilling and Blasting		
Labour	0·014	
Equipment	0·004	
Material	0·046	
		0·064
Loading		
Labour	0·039	
Equipment	0·088	
Material	0·020	
		0·147
Haulage		
Labour	0·051	
Equipment	0·036	
Material	0·021	
		0·108
Total		$ 0·387

Workings No. 33

Nature of Deposit. In this deposit a hard grey shale is interbedded with limestone and sandstone. The pit opened shows a 45-foot face underlying 10 to 15 feet of clay overburden.

Output. From this pit 110 tons of shale is removed daily for the manufacture of hollow building tile. A small percentage of clay is added to assist the flow of the shale through the dies.

Winning. The shale, with its associated rocks, is blasted loose from the face of the pit, then separated and loaded by hand into wooden cars.

Haulage. The wooden cars, which have a rated capacity of $1\frac{3}{4}$ yards but usually carry 2 yards, are hauled separately by cable out of the pit to a crushing plant.

Overburden. The heavy overburden is removed by steam shovel, the work being done, not by the operators themselves, but by contract. The cost of removal is based on yardage. Sufficient overburden is removed in one season for the following three seasons' work.

Drainage. It is necessary to keep a pump working in the pit for 12 hours per day. This centrifugal pump operated by a 15 h.p. motor raises the water 100 feet at a rate of 275 gallons per minute. As the pump is capable of lifting to a height of 120 feet at a rate between 400 and 500 gallons per minute, the pit can be kept workable even during abnormally wet weather.

Cost per Ton of Shale

Supervision		$ 0·047
Overburden		0·040
Drilling and Blasting		
Labour	$ 0·134	
Equipment	0·002	
Material	0·030	
		0·166
Haulage		
Labour	0·033	
Equipment	0·023	
Material	0·018	
		0·074
General		
Equipment	0·004	
Material	0·011	
		0·015
Total		$ 0·342

Workings No. 34

Nature of Deposit. The 23 feet of shale exposed at this working underlie a 10-foot bed of boulder clay. The shale bed itself has the following cross-section from top to bottom.

3 feet. Light buff-burning shale.
8 feet. Light red-burning shale.
2 feet. Dark buff-burning shale.
10 feet. Dark red-burning shale.

Output. Sufficient shale is removed from this working to run a plant having an average capacity of 20,000 dry-press brick per day. The plant operates 10 hours per day for a period of 9 months.

Overburden. This is removed by hand as the operation progresses.

Winning. The shale is blasted loose from whichever shale bed the material is required; it is then sorted and loaded by hand into steel cars.

Haulage. The loaded cars are drawn to the plant, a distance of 450 feet, by cable working in connection with a drum which receives its power from the plant main shaft.

Storage. No provision has been made for storage.

Drainage. No special provision has been made in this connection.

Cost per Ton of Shale

Drilling and Blasting		
Labour	$ 0·054	
Material	0·040	
		$ 0·094
Overburden		
Labour	0·150	
Equipment	0·004	
		0·154
Loading		
Labour	0·200	
Equipment	0·004	
		0·204
Haulage		
Labour	0·050	
Equipment	0·006	
		0·056
Total		$ 0·508

Workings No. 36

The general procedure for handling the material in this operation is quite different from any other met with during the course of this study.

At this deposit there are two clays: on top, a bed of red-burning averaging 11 feet; and underlying this, a bed of buff-burning clay averaging 4 feet; the former varying in places from 4 feet to 18 feet, and the latter from 1 foot to 7 feet.

After having operated for about 100 days in the course of the summer months, and having produced an average of 15,000 soft-mud brick per day, the plant is generally closed down. By this time the stock-pile has been used up, and more clay must be hauled from the deposit to an out-of-door's storage-pile. Two wagons are used in hauling the clay which a two-wheeled scraper has gathered. The clay is allowed to weather during the winter in the pile and is ready for brick production in the spring.

From what figures were available it has been computed that the clay-winning cost, per ton of clay, is as follows:—

—	To storage	Storage to plant	Total
	$	$	$
Red clay	0·36	0·27	0·63
White clay	0·50	0·27	0·77

The place where the clay has been piled year after year is a regular water-hole. The water which gathers here, especially in the spring, is removed by a bucket pump operated by a 10 h.p. motor which runs on an average of 120 hours per manufacturing season.

Comment. The double handling of this material adds considerably to the cost of manufacture, and it is doubtful whether the weathering effect is of such value to the soft-mud product as to warrant its continuance.

Workings No. 37

Deposit. In the pit 10 feet of wet, grey stoneless clay is exposed, under which can be seen 18 inches of a wet, blue sandy clay.

Output. From the clay bed 85 tons of clay is taken daily to be used in the manufacture of hollow building tile. The plant operates on an average of 9 months in the year and very little trouble is met with in the clay operation.

Winning. An electrically-operated shovel provided with a $1\frac{1}{4}$-yard bucket digs into the clay bank and loads the clay into waiting cars.

Haulage. The cars are hauled by a gasoline locomotive a distance of 460 feet to the plant where the clay is dumped into bins.

Storage. No great amount of storage is provided.

Drainage. No special provision is made, the natural slope of the hill upon which the pit is located providing efficient drainage.

Cost per Ton of Clay

Digging and Loading		
Labour	$0·102	
Equipment	0·042	
Material	0·001	
		$0·145
Haulage		
Labour	0·043	
Equipment	0·038	
Material	0·018	
		0·099
		$0·244

Workings No. 38

Deposit. The shale covers a large acreage and underlies a bed of clay which averages 1 foot in thickness. Limestone strata are met with at intervals and at some places there is more stone than shale, while in other places the shale is clean. The deposit is worked from the surface to a depth of 8 feet, but more shale lies underneath.

Output. One hundred tons of shale is won daily for the production of brick and tile.

Winning. The removal of the stone from the shale presents quite a problem, and at present it is accomplished as follows: the bed is ripped by a large steam shovel carrying a 3-yard bucket, the loosened material being turned over and placed into ridges as the shovel advances. It is allowed to weather for five or six years. At the end of this time the stone can be removed as all the shale has weathered free of the rock.

In the weathered state the shale is loaded by a 1¼-yard steam shovel into cars. If, however, the stone is much broken up it must be removed by hand and in certain parts of the working it is necessary to employ two men on this work.

In winter the weathered shale freezes in place, necessitating the use of the large shovel for loading.

Haulage. Wooden, side-dump cars, containing 3 yards, are loaded and hauled by locomotive to the base of an incline, up which they are hoisted and dumped into bins.

Overburden. The shale is mixed with the clay overburden to procure better working properties.

Drainage. No mechanical means of drainage is necessary, water draining naturally to previously worked holes.

Cost per Ton of Shale

Digging, Loading, and Cleaning		
Labour	$0·064	
Equipment	0·081	
Material	0·024	
		$0·169
Hauling and Unloading		
Labour	0·060	
Equipment	0·054	
Material	0·015	
		0·129
General		
Equipment	0·012	
		0·012
		$0·310

Workings No. 40

Deposit. This deposit is an 8-foot bed of grey clay, which contains not only boulders but also streaks of blue clay and lenses of silt. The grey clay is desired; the boulders are removed when digging, the smaller stones being removed at the plant. The overburden consists of 1 foot of top soil which is mixed with the clay and sent to the machine.

Output. Sufficient clay is removed daily for the manufacture of 50,000 soft-mud brick. The plant operates 10 hours per day for 4½ months in the year.

Winning. The clay is won by the use of a ¾-yard steam shovel loading directly from the bank into a wooden car.

Haulage. One car is used to haul the clay. Being loaded, the car is lowered by cable, 220 feet, to a point from which a drum operating in the plant hauls it up 12 feet over a distance of 260 feet to the hopper of the brick machine, where it is emptied.

Overburden. There is no removal of overburden, the top soil being dug and mixed with the clay.

Drainage. Drainage is natural. As there are no men working on the ground, wet weather does not interfere to any extent with the working.

Cost per Ton of Clay

Digging and Loading		
Labour	$0·076	
Equipment	0·086	
Material	0·029	
		$0·191
Haulage		
Labour	0·038	
Equipment	0·019	
		0·057
Total		$0·248

Workings No. 42

Deposit. This deposit is in hilly country and the opening made into one of the hills shows 6 inches of loamy soil, overlying 11 feet of grey clay. Drilling has shown blue clay to a known depth of 18 feet underneath the grey clay.

Output. This operation provides sufficient clay daily for the manufacture of from 35,000 to 40,000 soft-mud brick.

Overburden. The 6-inch layer of loamy soil is removed by hand as the operation progresses.

Winning. The clay is removed by a 1-yard steam shovel, which takes the clay direct from the bank and loads it into horse-drawn wagons.

Haulage. The clay is hauled in horse-drawn wagons to the plant, where it is placed directly into the hopper of the brick machines. The haulage distance is 500 yards.

Storage. There is no provision for storage of the clay.

Drainage The pit drains naturally.

Cost per Ton of Clay

Overburden		
Labour	$0·020	$0·020
Digging and Loading		
Labour	0·053	
Equipment	0·123	
Material	0·027	0·203
Haulage		
Labour	0·080	
Equipment	0·056	0·136
Total		$0·359

Workings No. 43

Deposit. This operation is located in rather hilly country. The opening made into one of these hills shows 9 feet (the working-face) of hard, dark grey clay, underlying 16 inches of top soil.

Output. This operation provides sufficient clay daily for the manufacture of from 50,000 to 55,000 stiff-mud brick. The plant operates 10 months in the year.

Winning. The clay is removed by a ¾-yard steam shovel which takes the clay direct from the bank and loads it into waiting cars.

Haulage. The clay is hauled in two 2-yard cars which are hitched together and are drawn by cable to and from the plant, a distance of 650 feet. Power for the cable is obtained from the main shaft of the plant.

Storage. There is no provision for storage of the clay.

Drainage. Drainage is natural.

Cost per Ton of Clay

Digging and Loading		
Labour	$0·050	
Equipment	0·036	
Material	0·016	$0·102
Haulage		
Labour	0·027	
Equipment	0·011	0·038
Total		$0·140

Workings No. 44

Deposit. Underlying a clay overburden which varies in thickness up to 25 feet, and averages 5 feet, is a tilted bed of hard, grey shale. The bank as exposed shows a height of 200 feet of shale.

Output. This operation provides 350 tons of shale daily for the manufacture of building brick and building tile. The plant operates 10 hours per day for 10 months in the year.

Winning. The shale is blasted loose and loaded by steam shovel into waiting cars. The overburden, being a rather plastic clay, is mixed with the shale.

Haulage. The loaded wooden cars are hauled by drum and cable arrangement to the plant, a distance of 100 yards, where they are dumped into storage bins.

Drainage. Drainage is natural.

Cost per Ton of Clay

Quarrying		
Labour	$0·020	
Equipment	0·006	
Material	0·013	
		$0·039
Loading		
Labour	0·023	
Equipment	0·021	
Material	0·035	
		0·079
Haulage		
Labour	0·047	
Equipment	0·021	
Material	0·003	
		0·071
Total		$0·189

Workings No. 45

Deposit. This pit, which is located in level country, shows 14 feet of a tough, wet, fine-grained brown clay containing small stones. The upper part of the clay is very short, whereas the lower part is very plastic. The clay in the bank contains approximately 22 per cent of water the year round.

Output. The operation produces 50 tons of clay per day which is used in the manufacture of drain tile and building tile. The plant operates 10 hours per day for 7 months in the year.

Winning. The clay is dug by hand from 4-foot benches, the ordinary spade being used. The top clay and bottom clay are mixed as they are loaded into the cars. Most of the stones are removed at the plant.

Haulage. The wooden cars which carry the clay are hauled by drum and cable operated from the plant. The haulage distance is 525 feet. including 150 feet of a 20 per cent grade from the pit bottom to the plant.

Storage. No provision is made for storage of the clay.

Drainage. In the spring the pit floor is flooded with water, which necessitates operating an electric pump for 72 hours steadily. After sufficient water has been removed by this means to permit working, a steam syphon is installed in place of the electric pump and this is sufficient to keep the pit dry all season.

Drying Clay. As the clay normally contains 22 per cent of water it is too wet for use in the machine. To overcome this, clay is gathered from the top of the deposit, which, being exposed to the sun and wind. keeps fairly dry, and put into a storage shed from which it is fed through the floor to cars and hauled to the plant to be mixed with the wet clay.

Cost per Ton of Dry Clay

Digging and Loading		
Dry Clay (including storage)		
Labour..	$ 0·327	
Equipment..	0·061	
		$0·388
Wet Clay		
Labour..	0·232	
Equipment..	0·007	
		0·239
Haulage		
Labour..	0·112	
Equipment..	0·025	
		0·137
General		
Equipment..	0·013	
		0·013
Total..		$ 0·777

Workings No. 46

Deposit. The exposed bank here shows 50 feet of hard, grey shale, the bedding of which is tilted. On top of this shale is 3 feet of clay overburden which is not removed, but added as wanted to the shale to promote plasticity. The deposit is located in very hilly country, the operation being carried on at the base of a high hill, with the plant close by.

Output. This operation provides 180 tons of shale per day for the manufacture of building brick and building tile. The plant operates the year round on a 10-hour day.

Winning. The shale is blasted loose, and loaded by a $\frac{5}{8}$-yard steam shovel into waiting cars.

Haulage. The material is hauled in $\frac{3}{4}$-yard steel cars by drum and cable, operated from the main power shaft, a distance of 275 feet to the plant.

Storage. No provision is made for storage.

Drainage. Drainage is natural.

Cost per Ton of Shale

Drilling and Blasting		
Labour..	$ 0·054	
Equipment..	0·007	
Material..	0·025	
		$ 0·086
Loading		
Labour..	0·088	
Equipment..	0·015	
Material..	0·013	
		0·116
Haulage		
Labour..	0·018	
Equipment..	0·011	
		0·029
Total..		$ 0·231

Workings No. 47

Deposit. This is a 65-foot bed of fairly clean clay overlying a 21-foot bed of sand, gravel, and boulder clay.

Output. From this operation 90 tons of clay are removed daily for the manufacture of soft-mud common brick. The operation continues for 9 months in the year, on a 9-hour day.

Winning. The clay is blasted loose from the bank and loaded by steam shovel into waiting cars. The shovel operator attends to the boiler.

Haulage. The clay is loaded into 1½-yard steel cars, of which there are two, and hauled by horse over fairly well kept tracks to the plant, a distance of 750 feet.

Storage. There is no provision for storage.

Drainage. Drainage is natural.

Cost per Ton of Clay

Supervision		$ 0·030
Blasting		
Labour	$ 0·005	
Material	0·009	
		0·014
Loading		
Labour	0·051	
Equipment	0·045	
Material	0·034	
		0·130
Haulage		
Labour	0·045	
Equipment	0·024	
		0·069
Total		$ 0·243

Workings No. 48

Nature of Deposit. At this deposit a tough, clean, buff-burning clay lies in a 40-foot bed under a thin silty overburden.

Output. For nine months in the year this operation provides a plant with an average of 100 tons of clay per day. The clay is used in the manufacture of common and face brick.

Winning. The clay is blasted loose and loaded by steam shovel into cars.

Haulage. The 1½-yard cars are hauled by mule, two at a time, some 240 yards to the top of an incline down which the full cars gravitate singly (hauling an empty car up as they descend). At the bottom they are hauled by horses to the plant, a distance of 50 yards.

Storage. No provision is made for storage.

Drainage. Drainage is natural. On very wet days the travelling is hard, but generally little trouble is met with in this connection.

Cost per Ton of Clay

Supervision		$ 0·027
Overburden		
Labour		0·045
Drilling and Blasting		
Labour	$ 0·005	
Equipment	0·002	
Material	0·009	
		0·016
Loading		
Labour	0·091	
Equipment	0·074	
Material	0·025	
		0·190
Haulage		
Labour	0·081	
Equipment	0·039	
		0·120
Total		$ 0·398

SUMMARY

The winning of clay and shale at an economical cost is carried out under such a wide range of conditions as to make a direct comparison of little value. So much depends upon the operator, the attitude of the labour involved, the nature of the material and the conformation of the country, that each workings must be treated as one of a type both with regard to method of working and cost of operation.

The data accumulated during the present study, as has been found in similar studies in other localities, are therefore difficult to correlate. It is possible, however, to recognize features that contribute to either good or poor operation.

When considering the reorganization of an old working much depends upon the original plan of development and on the capital expended, changes in the method of handling such a project may not be always economical and can be very impractical.

The subject of winning the material should receive closer attention both as regards systematic working and the cost of the raw material. There are operators who fully appreciate the importance of this, but many treat the pit in a rather niggardly fashion.

Before starting a pit, as much consideration ought to be given to the mode of development and working as to the subject of plant layout. The plant is entirely dependent upon the pit for its source of supply, and anything that can be done at the outset to ensure the proper material at the most economical cost over a long period should be carefully considered. Even should it be impossible at the outset to set up the method that will ultimately prove the best, the workings should be developed with this end in mind, so that when circumstances permit it will be possible to change over. The consideration of such factors as removal of overburden, acreage involved, required daily output, wetness of material, drainage, presence of stone, desirability of weathering, desirability of benching, should not be put off until it may be difficult or impossible to apply the plan desired.

Overburden. The removal of overburden is costly. It can and does in some cases equal the cost of winning the material. It is essentially a winning operation itself as it necessitates excavation and transportation. Where to place the overburden is of most importance, because old workings are not always available. Should it be a very serious matter, or likely to become so, involving considerable transportation, it might prove economical, particularly for small- and intermediate-size plants, to have the removal done by contract. Otherwise, it will be necessary to purchase additional equipment, which will probably not be worked to full capacity, and which will be an unnecessary charge upon the winning operation proper.

Drilling and Blasting. This subject could very well form a special study with particular regard to the needs and demands of the clayworker. Much information is available relative to the general use of explosives, but the clay-winner has certain peculiar problems relating to daily tonnage and clean workings that are different. Such a study would result in a better working knowledge of explosives for the clay- and shale-winner and in economies in the cost of winning.

The explosives manufacturers have men well equipped to advise upon their use, and their services should be enlisted.

Digging and Loading. The removal of clay and shale from their natural beds may be done economically either by labour or by machine, depending upon the size of the workings. Before the purchase of equipment the operator should assure himself of its suitability for his material. It is wiser to purchase a machine on the heavy side for any particular job, but a machine that is adaptable to several purposes is better for a medium-size plant. On large operations more elaborate and less flexible machines are warranted. Thought should be given to the auxiliary equipment or auxiliary set-up for use when the main equipment is under repair. The features desired in the equipment should be decided upon in order that the specific problems of uniformity, output, etc., are provided for.

Transportation. Transportation can be decided upon only after an actual inspection of the needs. The lay of the material in relation to the plant and the daily requirements must be known, and such factors as distance to be covered, conformation of country, and intervening obstructions must be adequately allowed for. Each type of transportation set-up has its strong and weak points.

Keeping Costs. The keeping of actual costs in clay-winning operations is not always simple. True enough, if the layout is such as to function orderly at all times the task is not difficult. There are, however, times when spare men are put into the workings to overcome a possible shortage of material, times when labour is taken from one job and placed on another, especially during hold-ups, when hold-ups are met with and loss of time involved, and the proper allocation of the costs of such manoeuvres requires systematic accounting. However, those who have patience enough to do so have been able to find their cost and have benefited accordingly.

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"	"	"	"	"		3058,	December,	1930
"	"	"	"	"		3123,	June,	1931

See also:

U.	S.	Bur.	of	Mines	R. I.	2953,	August,	1929
"	"	"	"	"		2958,	September,	1929
"	"	"	"	"		2962,	October,	1929
"	"	"	"	"		2972,	November,	1929
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