SIMPLE FIRING TECHNIQUES IN CERAMICS

FOR SECOND CYCLE INSTITUTIONS

A Long Essay Submitted to the College of Art, University of Science and Technology, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE POSTGRADUATE DIPLOMA IN ART EDUCATION

By

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PREFACE

The problems of firing any ceramic work can be overcome as long as the basic principles of clay firing are adhered to. Beginners can be self sufficient in firing provided they study existing firing processes and adapt them to suit their situation. To be self sufficient, one has to be innovative and resourceful so with the methods provided in this study, it is my fervent hope that teachers will experiment with other methods and materials.

This study is devoted to the provision of some selected firing methods for use in the second cycle institutions of Ghana. It includes open firing processes, updraft and downdraft kilns made from landforms, and some simple means of obtaining attractive finishes with the firing processes under investigation. It does not include glost firing nor does it cover the use of electricity, gas or oil.

The study was done with the author's

observation and involvement in the processes of firing. Some of the information were sought through interviews and others through books. The information is presented in as practicable a form as possible, with step-by-step illustrations designed to throw more light on the descriptions.

ACKNOWLEDGEMENTS

The dessertation includes talents and generosity of many persons. My sincere thanks go to my supervisor, Nana Amponsaa Opoku-Asare (Mrs) whose guidance and directions have yielded this piece. My gratitude goes to the potters at Pankronon for their generosity.

Thanks also go to Miss Gladys Baidoo, Miss R. Hockman, Master Daniel Yaw Brefo, Miss Hope Marfo and all who helped in diverse ways in the writing of this thesis.

Finally, my special appreciation goes to my wife, Susie, for her patient co-operation and motivation. In fact she has been an unfailing source of encouragement and hope.

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CHAPTER ONE

INTRODUCTION

Although most teachers teach ceramics, very few of them are able to preserve the students works as they do to the other art works. Some of the students' works are unique and need to be preserved but surprisingly they are left in the bone dry, fragile state to break. Some of such pieces are re-cycled whilst others are swept from the art rooms into bins.

The effect of this attitude of teachers is the disinterest which students show in clay-work because they see it as valueless.

Most of the teachers interviewed in the preliminary enquiry about firing complained of lack of funds and technical know how for the construction of kilns. To them firing cannot be made possible without conventional kilns. The schools with kilns do firing about once in a year, following the same firing procedure without any variation.

This then is the task of the study: to provide some simple firing techniques that require less expensive means. It is intended to make firing a simple and easy job which can be accomplished in any school environment. The firing methods provided have been subjected to preliminary trials by the author and have proved to be workable.

THE PROBLEM AND ITS SETTING

The statement of the problem

The purpose of this essay is to provide the second cycle institutions of Ghana with some simple firing techniques that require less expensive means.

Objectives

1. To identify open firing methods that are suitable for firing clay wares in Teacher Training Colleges and Secondary schools.
2. To expose some natural landforms that can be converted into kilns for firing purposes.
3. To suggest some simple, attractive and effective finishes that can be achieved by means of firing.

Delimitations

The study is limited to the use of materials, equipment and fuels which are locally available.

DEFINITION OF TERMS

Bagwall : A brick structure which prevents the intense heat of the furnace from striking directly on to the wares.

Chequer : A loose brick arrangement in the kiln to form a base shelf for the stacking of wares.

Down-draft kilns : Kilns with the arrangement of flues and chimney causing the flames to travel downward over or between the wares.

Dunting : Fracturing of pieces by uneven or fast cooling.

Firebars : Metal bars arranged in the firemouth of a kiln, for the holding of solid fuels.

Grog : Coarse, medium or fine ground clay bisque added to a clay body to reduce warpage, shrinkage and cracking: also used to add texture to a clay surface.

Oxidation Fire : A kiln fired with a full supply of oxygen.

Primary Air : Air which enters the burners and mixes with the gas before combustion.

Sherd (Shard): A broken piece of pottery.

Reduction firing: A firing in which there is insufficient oxygen available to consume the free carbon emanating from the heated clay, resulting in the formation of carbon

Sagger: The chamber in a kiln holding ceramic pieces apart from the firing chamber, usually in a fuel-burning kiln.

Secondary air : Air that enters through the fire port and adds oxygen to the flame.

Skewback : A slanted face of a wall where an arch exerts a thrust.

Updraft kiln : A kiln with the arrangement of flue and chimney at the top causing the flames to travel upwards through the wares.

Assumptions

1. Clay wares produced in most second cycle institutions are not fired because they lack knowledge of firing without conventional kilns.
2. Institutions that fire their wares are unable to achieve attractive surface effects.

The importance of the study.

The study will expose art teachers and students to firing techniques that can be adapted for the school situation.

It will enable students to fire their wares cheaply and effectively and to achieve very attractive surface effects.

Review of Related Literature

Amoah (1966) studied pottery making at Pankrono. On firings, his work highlighted on the open firing process, emphasizing on smoking as a form of finish to the pottery products.

Rhodes (1968) worked on the design, construction and the operation of kilns. He traced the history of kilns from the open firing to modern electric kilns in use today.

Cardew (1969) worked on primitive open firing, terracota firing, high temperature firing, kiln designing, building, setting, cooling and firing defects. On all these, he provided some guidelines for the beginner.

Kokroko (1970) offers a study of pottery in the Volta region and his study provided information on methods of firing and smoking in the different parts of Volta Region.

Rhodes (1973) provides information on drying, oxidation and reduction, quartz inversions and vitrification.

Gregory (1977) offers a study on kiln buiding and his work covers practical information on planning, with construction and operation of kilns. However, respect to material selection, his work was a little foreign.

This thesis, however, seeks to analyse and suggest suitable firing methods that can be effectively adopted in Ghanaian schools and colleges.

Population for study

Random sampling of art teachers of some secondary schools and some potters at Pankrono were interviewed.

Data.

Information for the thesis was obtained from books, theses and by interviewing potters. The author's personal experience in kiln firing has also been documented.

Methodology

The descriptive, analytical and experimental methods were used.

Limitation

The delay in the payment of the thesis allowance which in itself was insufficient, coupled with the short semester break prevented me from performing some other experiments which could have enhanced the data presented.

CHAPTER TWO

OPEN FIRING PROCESS

This is the simplest form of firing that can be done in the second cycle schools of Ghana. It requires no fixed structures so firing can be done anywhere and with readily available fuel. The process involves surrounding the clay wares with red hot coals and embers and thus raising the temperature of the earthenware to red heat. The maximum temperature that can be achieved with this process is between 750°C and 800°C. Since this temperature is quite low, wares meant for this kind of firing must necessarily be made thick in order to increase their durability.

<u>Fuels</u>

The type of fuel used depends on the location of the school. Schools in the forest belt of Ghana can use firewood and wood shavings. Schools along the coast can rely on coconut husks and fronds. In the grassland areas, dried grasses, fine brush, corn stalks, twigs, millet and silk cotton stalks and corn cobs are excellent sources of fuel. In areas where cattle rearing is intensive, dried cow dung, which burns quite rapidly and retains its shape as an ember may be used as an effective fuel.

Water Smoking

It is the process of driving out moisture from clay during the early stages of firing. With the open firing processes, heat application to the ware is very rapid therefore very difficult to effect any gradual heating of the objects concerned. However, water smoking can be done by placing the thick objects over a smouldering fire to drive away the moisture in it. Hearths may be constructed to serve as a support for the objects so that the heat can circulate round the object during the pre-heating process. It can also be done by putting dry grass inside the pot and setting fire to it. In order to prevent the clay ware from re-absorbing atmospheric moisture the actual firing must proceed immediately after water smoking.

Firing

Firing may be started by lining the floor with dry twigs, branches or grass. On this lining, the wares to be fired are piled in a compact mass with as little empty space between as possible. The heavier wares are arranged first and the light ones placed on top.

After the first layer, the objects are covered with dry twigs. Another arrangement of the wares on top of the first layer should be made and the procedure continued till the last pot is packed. The setting tapers to the top in the form of a cone so as to prevent the wares from sliding out of the arrangement. The exposed wares at the sides of the setting are covered with fuel by leaning some more twigs against them until the wares are completely buried in the wood fuel. Fig. 1

Fig.1. The pottery is covered with light twigs and corns stalks

Fire should then be set to the heap at different places around it. As soon as the wood begins to burn, dry grass should be thrown on in armfuls to keep the fire going until the right temperature is achieved. The glowing heap of embers which cover the wares prevent draughts of cold air which can cause dunting from reaching the wares. At the end of the firing process the varying amounts of smoke produced by the fire at various levels of the heap results in red, black and mottled colours on the clay ware.

2. Firing can also be done by preparing a bed of firewood on the ground and pouring live charcoal at the corners of the bed. As the bed starts to smoke, the wares are piled on it with the heavy ones as first layer. These are then covered with fresh leaves. After a short period of smoking, dry materials such as twigs should be piled on. As the fuel burns wilder more fuel is added on to the heap. When the fire is about to die down, the wares should be covered with pieces of roofing sheets or any flat metal sheets to prevent the movement of cool air from blowing onto the hot wares to cause dunting. This method of firing does not require pre-heating because the smoke liberated tends to pre-heat the pieces.

3. <u>Open pit firing</u>

This can be done by digging a shallow pit of about

50cm deep and several square feet in area, depending on the volume of wares to be fired. Twigs branches or reeds are used to line the sides and bottom of the pit. On this lining the wares are packed with fuel stacked in and around them. Potshards are then placed over and around the setting. If these are not available, either broad tree backs or dried cow dung can be used:

The fuel must be set afire and allowed to burn rather slowly for an hour or two to bring about thorough drying. Since the fuel is in a shallow enclosure little air gets to it so the fire is not likely to burn intensely at the start. As heat begins to intensify more fuel should be piled on the wares to make it burn more fiercely. As more and more fuel is burned, a bed of red hot embers surround the wares and raise the temperature gradually to red heat.

As the entire pit and its contents reach red heat the fire is allowed to die down. The fire may be covered with wet leaves dried dung or ashes to help retain the heat in the pit. The unpacking ought to be done when the fire has completely died down. Fig.2

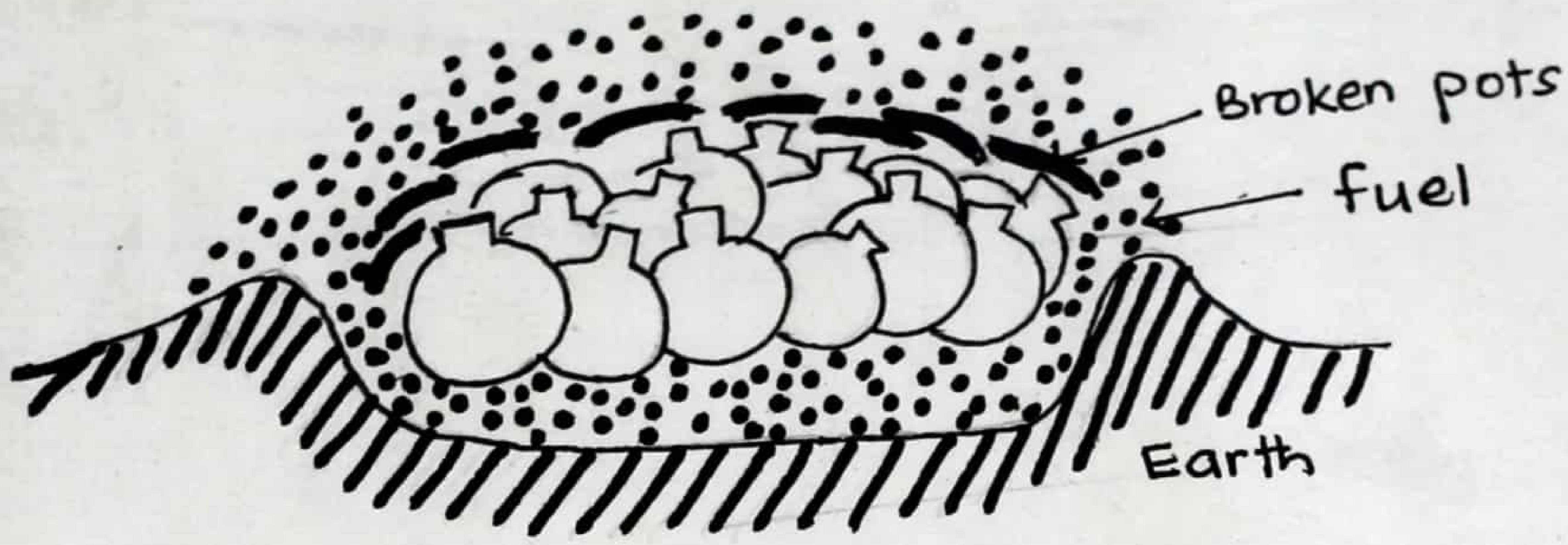


Fig.2 Pit Firing

4. Sawdust firing

This is done by first lining a prepared floor with sawdust to a thickness of about 8cm. The pieces to be fired are packed on top of this lining and more sawdust poured onto them until they are buried in it. The inside of the pots must be filled with sawdust so that heat work can be accomplished there.

A wall of loosely packed blocks or bricks around the setting helps to check the sawdust from flowing off. The height of the wall rises with the packed arrangement of wares to be fired. When the final set of pieces are in place, a heap of sawdust is poured over them. Fig. 3

Firing can be started at this stage by pouring kerosene at vantage points of the heap and setting fire to it. The fire should be allowed to burn until the sawdust changes into ashes. The unpacking should be done when everything has cooled down.

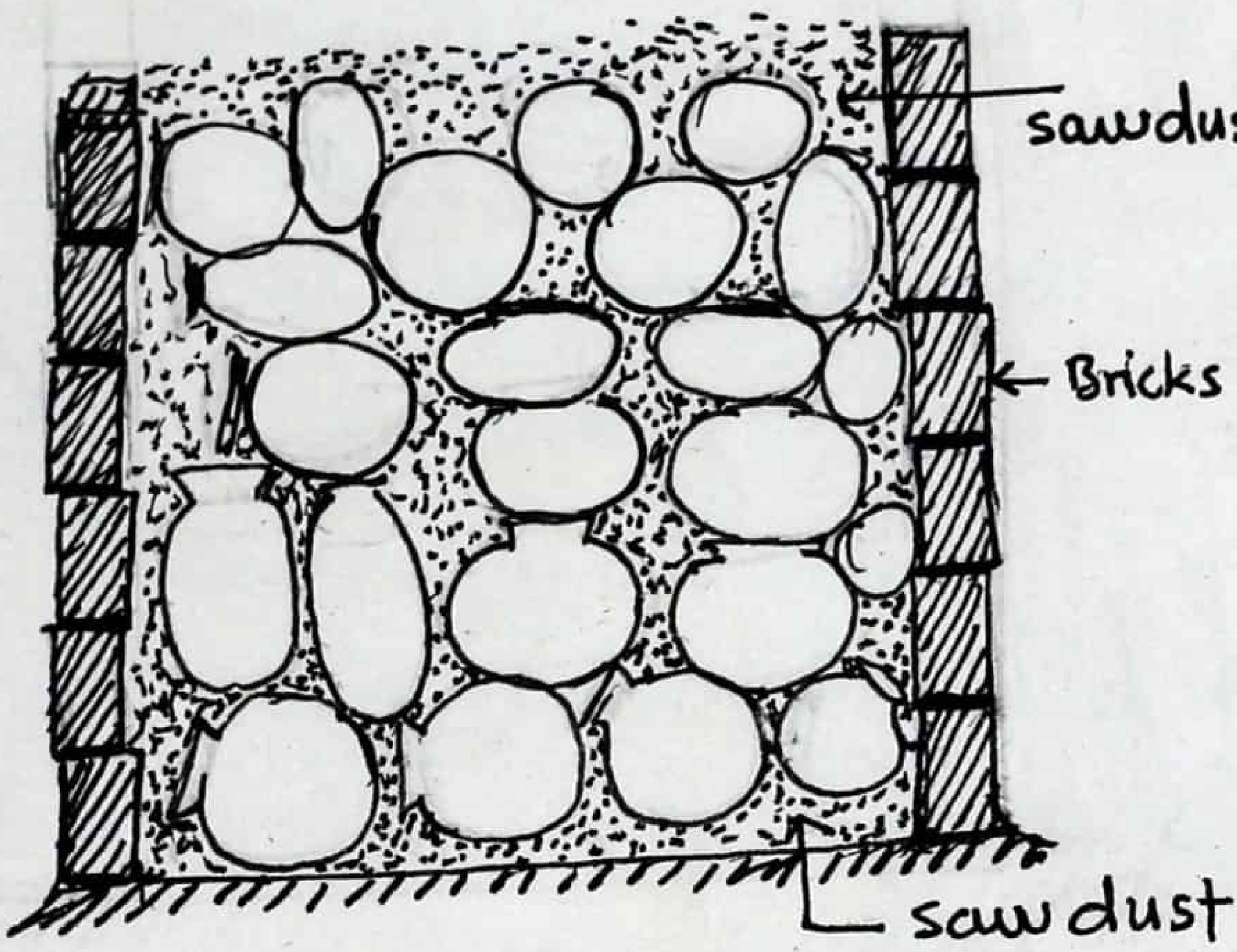


Fig.3 Sawdust "kiln"

To reduce the incidence of breakages in the course of firing, students should be advised to use coarse clay in modelling. Coarse clay is ideal for modelling because it dries quickly.

5. <u>Scove "kiln" firing</u>

This is a method of firing bricks without a conventional kiln. Like the other open firing methods, it requires no fixed structures but involves the simple arrangement of dry bricks as set in a kiln.

The bricks are piled loosely and in a manner which provides fire places at the sides of the structure. The chequer method of arrangement is ideal, Fig.8. This allows the fire free access to every part of the setting. As the setting progresses to the top, the bricks are packed closer so that the heat evenly spreads through before finally escaping. The chequer arrangement can be made to any height depending on the number of bricks being fired but too high a setting will bring about under-firing of the bricks at the top.

When the setting is complete, it is cased in a skin of similar bricks packed closely round it. This outer arrangement should give room for about two or three spaces around the setting to serve as fire places from where heat will be introduced to the setting. Fig.4

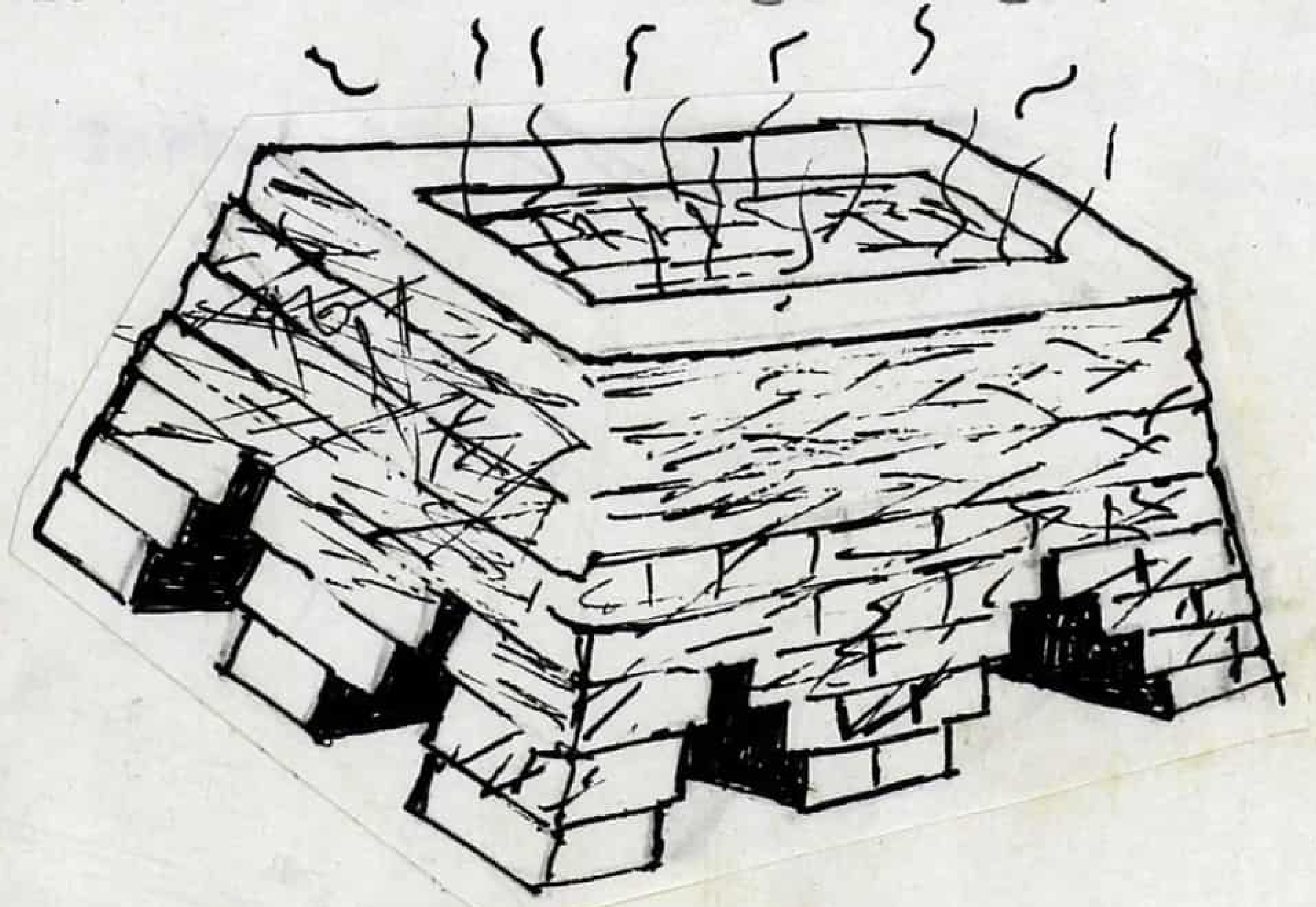


Fig.4 Scove 'kiln'

The fire places are built by means of a succession of slight corbels at each course with the bricks projecting about 3cm. to 4cm. from the course below. Fig. 5. Each fire place when complete is roughly a triangular opening of about 75cm wide at the base and about 90cm high.

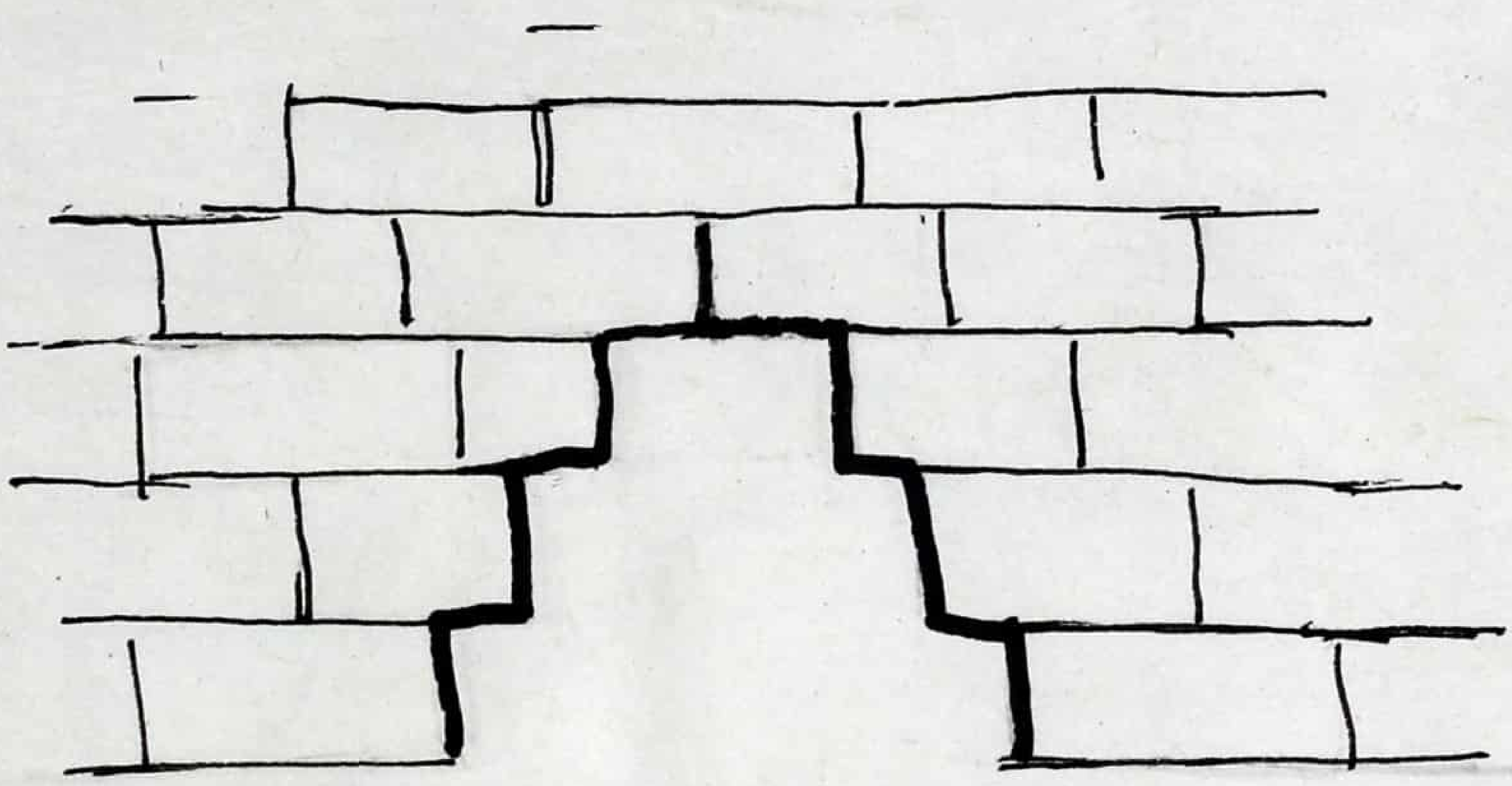


Fig.5 Corbel arch.

The outer surface of the arrangement is then plastered with a mixture of clay and grass leaving some chinks at the top for the escape of hot gases. Fig.4

Fire should be started at the fire places with about a couple of pieces of firewood in the first quater of the firing working the heat up gradually until enough moisture has been driven out from the bricks. The heat can be increased by increasing the quantity of pieces of firewood. As the fire increases, the interior part of the setting becomes red hot. The bricks outside the setting become under fired so they can be placed inside the setting, in the next firing. Bricks fired in this manner can be used to construct permanent kilns in schools and colleges.

CHAPTER THREE

KILNS FROM LANDFORMS

In school and college firing, temperatures between 900°C and 1,100°C are enough to bring maturity to most of the clays used. These temperatures can be achieved with simple updraft and downdraft kilns. These kilns can easily be constructed but in schools where availability of bricks and the skill needed for the construction of round structures with rectilinear bricks are lacking, natural landforms can be utilized. If properly altered, these landforms can become permanent means of firing in most schools.

The advantages of such kilns are many. For example, they need very little or no insulating bricks since the soil itself acts as a natural insulator while being self supporting.

1. <u>Compact mound kilns</u>

A simple round updraft kiln can be constructed by making a circular hole with a diameter of between 60cm and 75cm and about 100cm deep in a compact mound. Fig.6

Fig.6 A compact mound.

A trench of about one foot square is dug from the outer base of the mound to the floor of the round hole dug. The inner wall is then plastered with clay tempered with sand to fill in the voids that may be created in the walls.

The circular hole then becomes the firing chamber while the trench or passage way from outside the mound into the hollow mound becomes the hearth or fireport. Fig.7

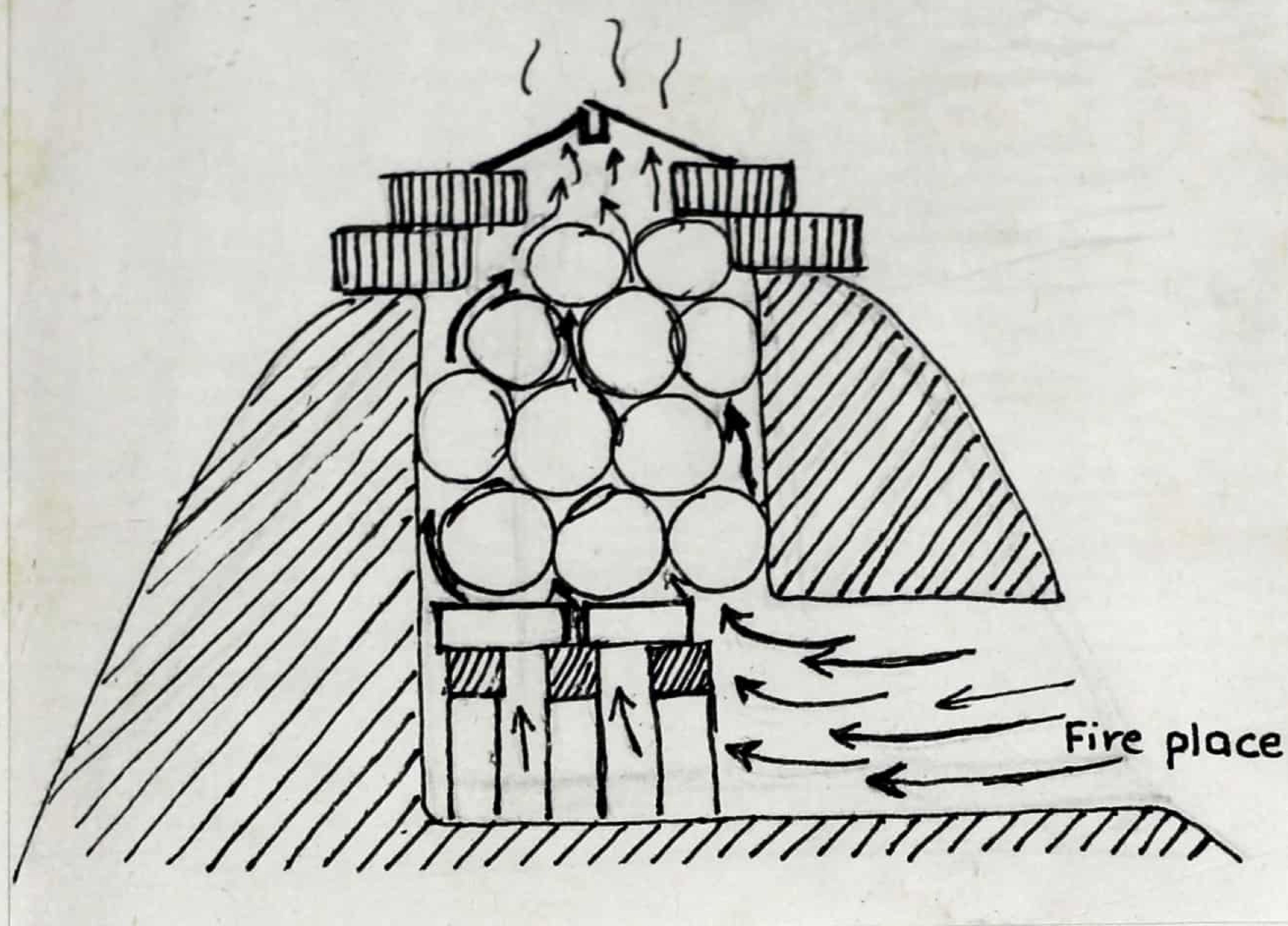
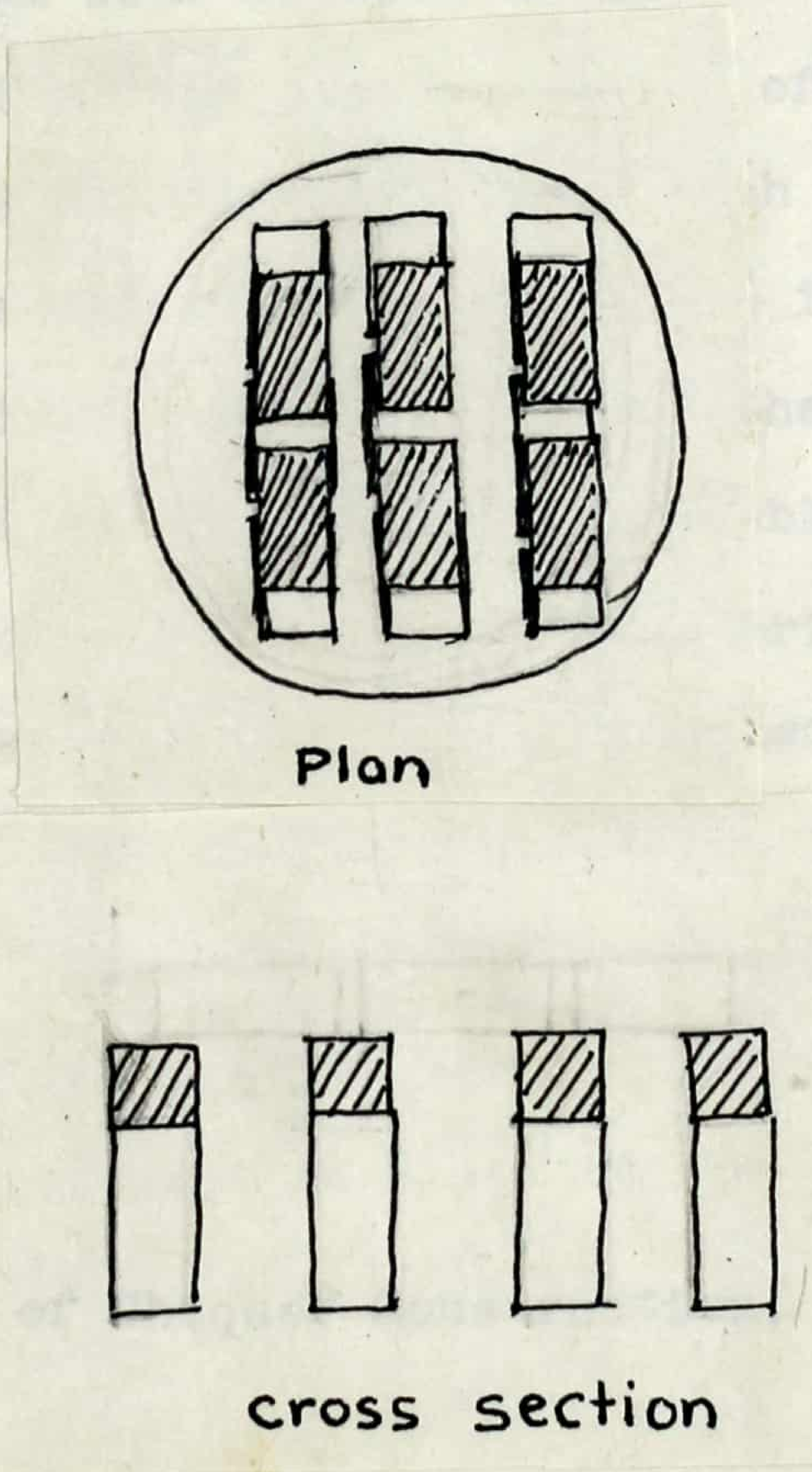


Fig. 7 A kiln from a compact mound.

Firing can be done in this hearth without hobs or firebars but the limiting factor to its use is the possible accumulation of partly-burnt charcoal which will collect in the hearth.

In such a situation, any attempts at raising the temperature in the kiln by stoking, results in the accumulation of embers which tend to reduce the amount of air needed to speed up combustion. This action results in a smothered fire which can be remedied by raking out the live charcoal in the course of firing. Raking is rather tiresome and must therefore be prevented by providing the fireplaces with hobs. Otherwise, kilns are to be provided with long hearths so that live charcoal can be pushed out through the exit end of the fire.

Before setting the kiln, a chequer must be built inside the chamber. This serves as a base shelf and if well constructed, can help bring about an even distribution of heat across the setting. Bricks with straight end-faces are desirable in the three tier chequer arrangement. In the first tier, bricks are stood on their ends while the other two have bricks laid out on their edges. This means that with normal sized bricks of 9 inches by $4\frac{1}{2}$ inches by $2\frac{1}{2}$ inches, the total height of the chequer will be 18 inches. Fig.8



a.

b

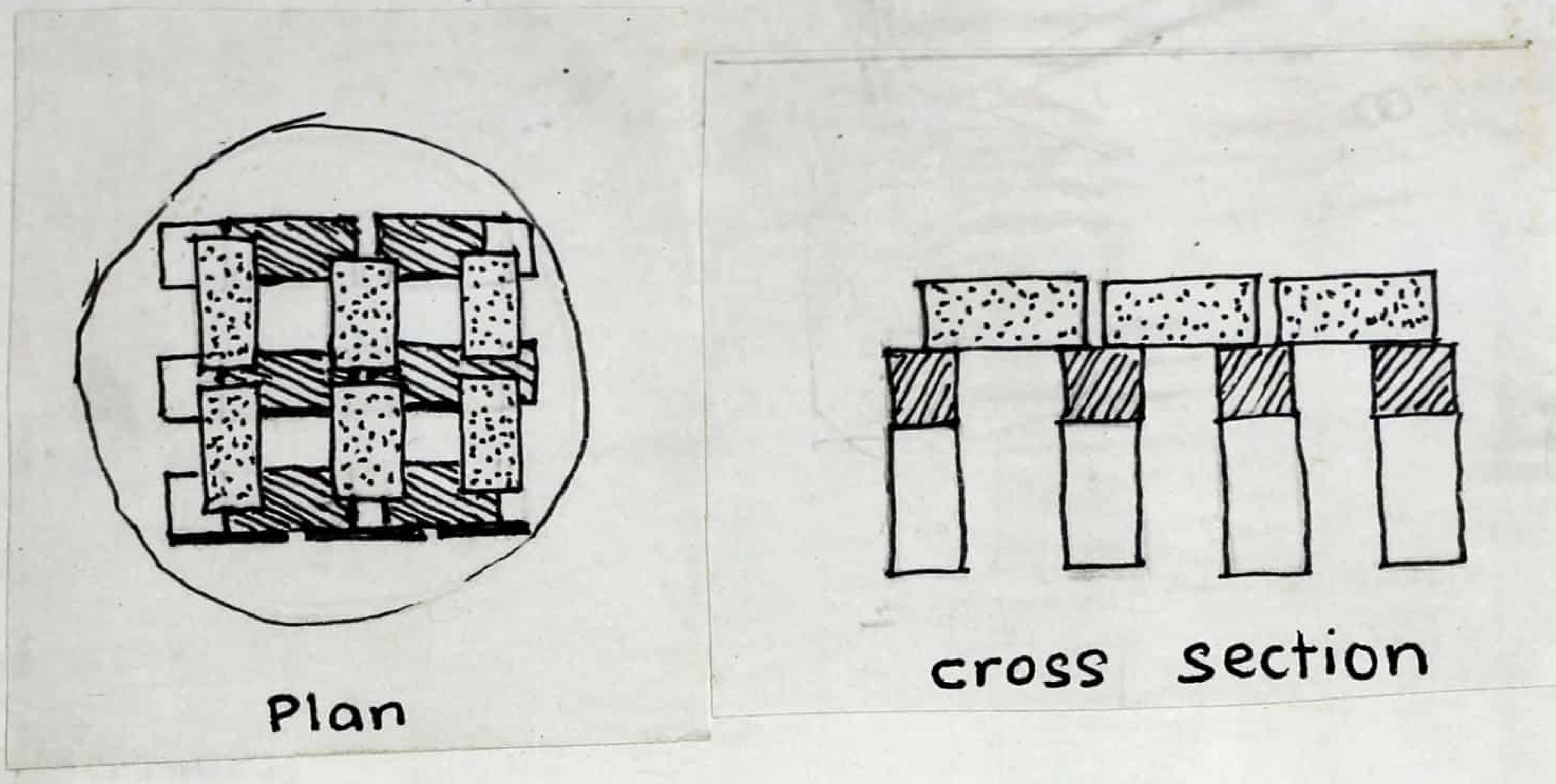


Fig 8 Stages of chequer construction

The floor of the hole is first given a coating of dry sand about 6½ centimeters thick to enable the supporting bricks to stand firm. The rows of bricks are placed about 15cm apart so that there is a path or channel 8cm wide between them. On these stretchers or bridges of bricks, another layer of bricks is laid ends touching so that with the 3 inch paths between each row, the structure measures 13½ inches high (9" + 4½") Fig.8. The addition of the third course or deck steadies the otherwise unstable structure at the second stage. These bricks bridge alternatively the spaces between the first two corners. Each brick therefore overlaps its neighbour by 6½cm so that they lock one another securely.

Half bricks can be used to fix the structure to the circular wall so that the whole deck is securely wedged in position.

On the deck, a layer of shards can be laid, allowing bigger spaces at the back to slightly block the area immediately above the entrance (throat) in order to induce the flames to spread out evenly over the floor.

The actual setting of pots should be so arranged that the strongest forms are at the bottom. Fragile items like lids, saucers, bowls and plates are laid upside down at the top to form a canopy which tends to regulate and evenly distribute the heat through the kiln.

When the kiln is nearly full, two or three more courses of bricks are laid without mortar, each projecting an inch inward so that the final diameter becomes 24 inches. An iron rod or a suitable piece of light angle-iron is next laid across the top. Shorter lengths of rods are then supported on this and over these a temporary roof of broken pots or tiles is made. Fig.9

The fire should be built at the entrance of the tunnel so that the flame and hot gases emitted flow upward through the wares and escape through the top. If split up and completely dry pieces of wood are used, a fiercely hot flame can be generated in the firemouth to produce a rapid build-up of temperature in the chamber.

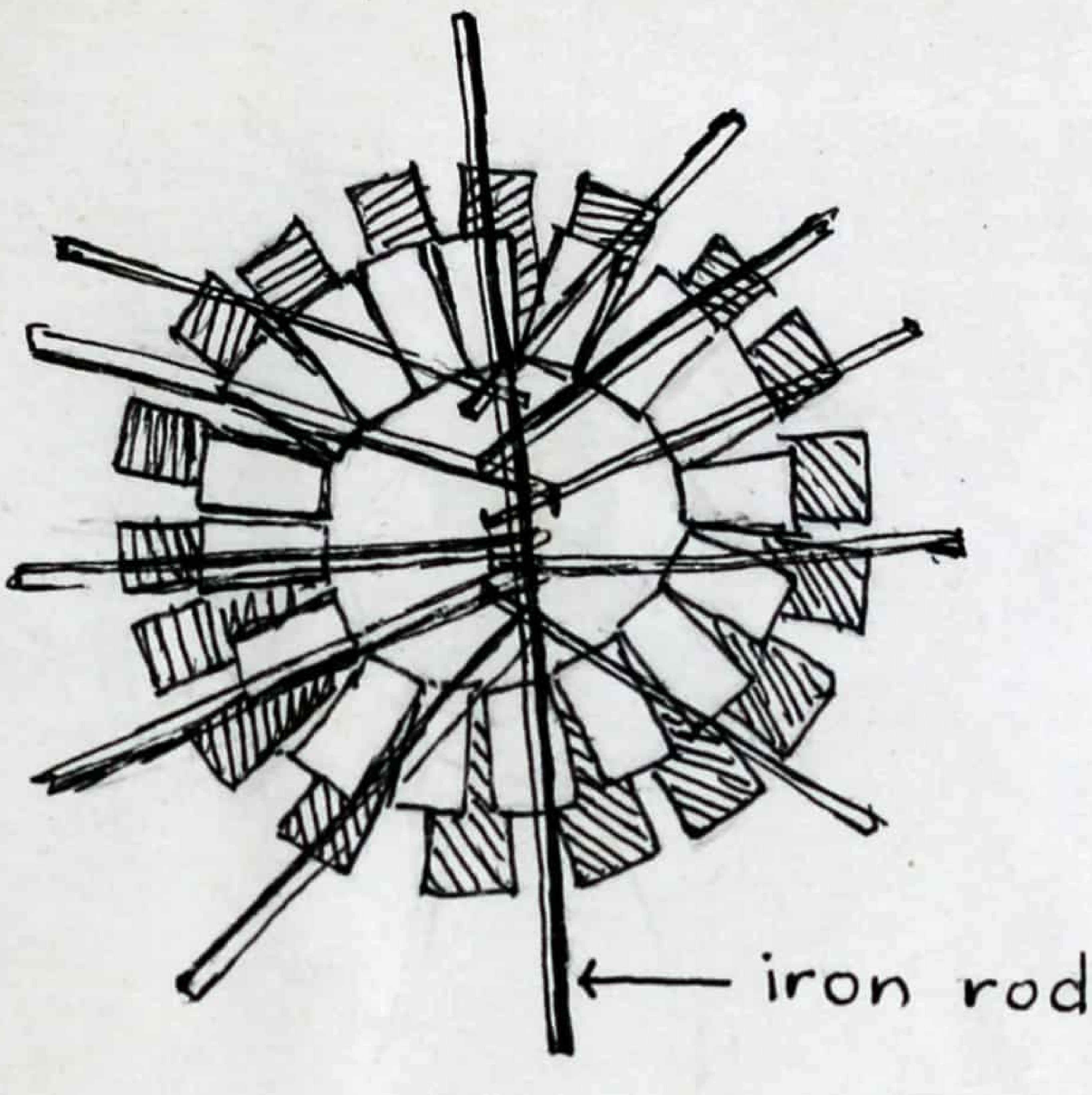


Fig. 9 Roofing the compact mound kiln. (Plan)

Like any other kiln it must have a firing chamber, a flue, a chimney and a packing chamber.

The firing chamber is constructed by digging a tunnel of about 1 foot square of varying length depending on the quantity of wares to be fired in it. A trench of about 16 feet is enough to give an excellent draft. The walls of the tunnel can either be lined with bricks or left bare, provided that the wall surface is compact. Alternatively, the walls can be plastured with a mixture of clay and sand. The floor of the trench may be covered with sand and the roof, constructed after each packing, made of fired clay slabs or bricks.

If bricks longer than the width of the tunnel are available the two sides can be bridged to form a simple lintel roof. Fig.11.a This is done by arranging the bricks compactly across the tunnel. Otherwise the top of the trench can be shaped to serve as a skewback.

Fig. 11.

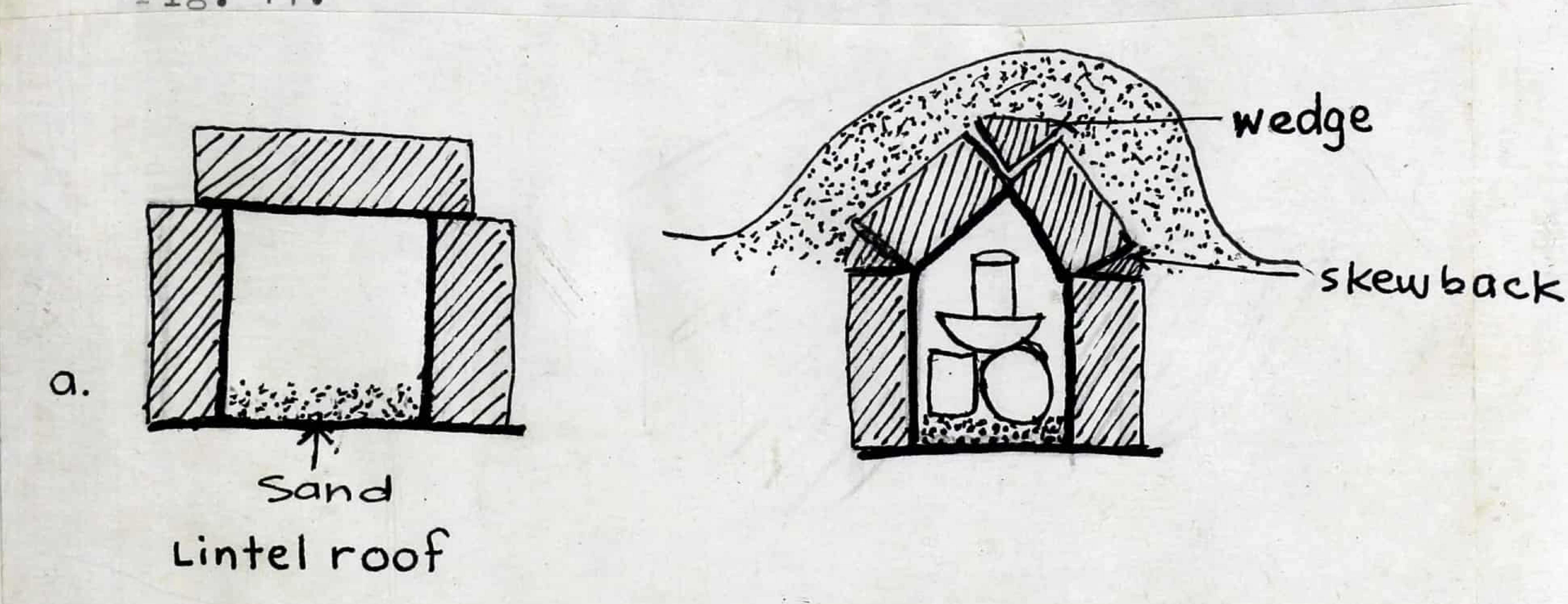


Fig. 11 Roffing a trench kiln.

An arrangement of pairs of bricks with each end resting on the skewback is made, serving as crown if the 'V' shaped spaces formed at the top by the ends are wedged.

This kiln needs stoke holes along the tunnel to help increase the temperature at the upper section. Some spaces must therefore be left open for this purpose when the roof is being built.

If slabs are available, they can be placed snugly on the tunnel and earth heaped over them for insulation.

In order to give it an additional draft, the upper end of the kiln can be given a chimney with either a galvanised iron pipe or an arrangement of two or three old metal buckets one on top of each other.

The main firebox built at the lower end of the tunnel consists of a deep rectangular hole dug at the lower end of the tunnel. The hole is lined with bricks leaving one side open. In the middle of the box, (about the height of the base of trench) notches are created and short iron rods are fixed as gratebars to hold the fire-wood fuel. The space underneath the grate bars is the ash hole. There should be air holes in the box to supply air for combustion. The firebox can be roofed in the same way as the trench. Fig. 12

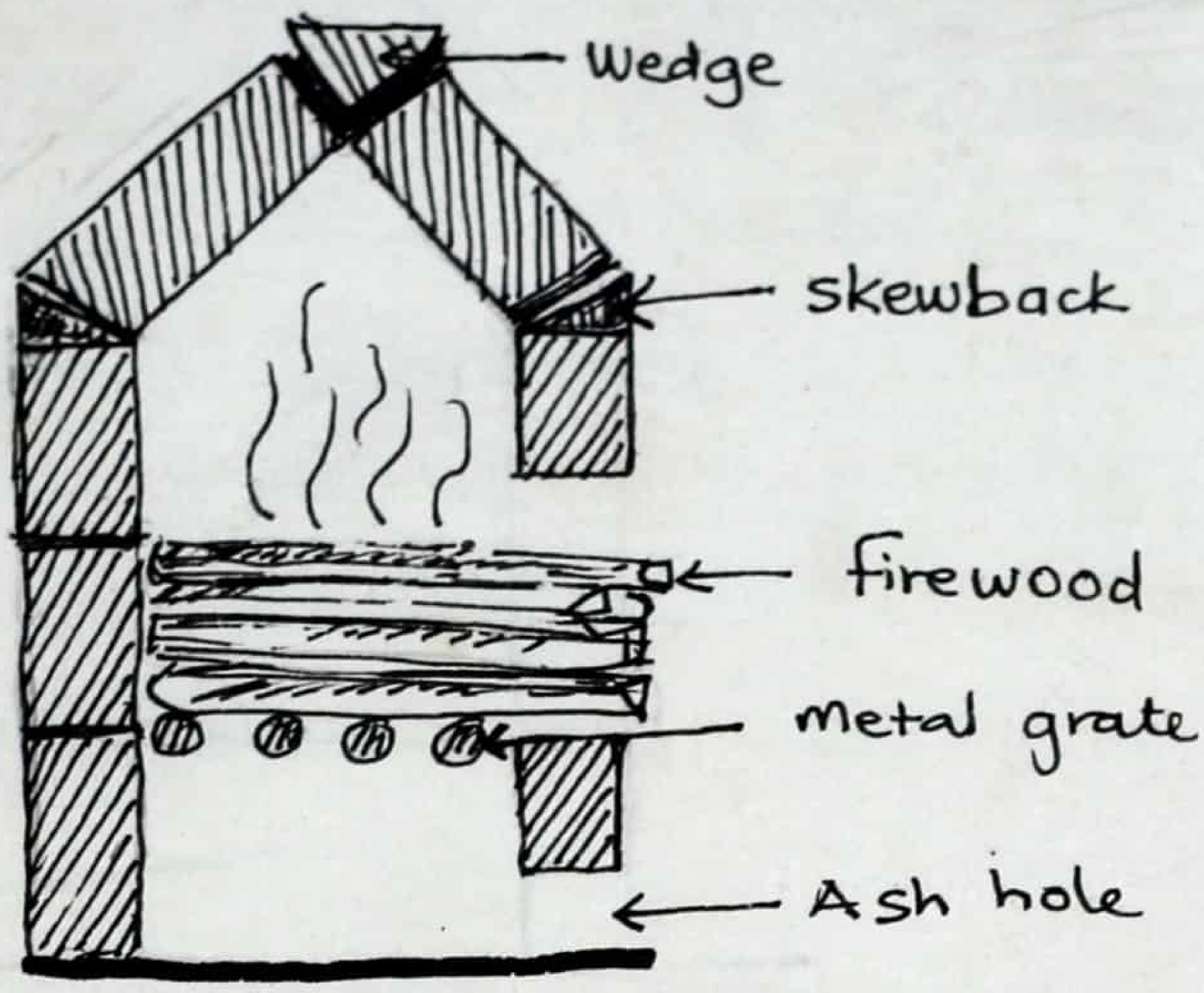


Fig. 12 Fireport (cross-section).

Before packing this kiln its floor is covered with a layer of sand and the wares set in rows on it with the smaller pieces stacked in the big ones.

Where the slope is very steep, the sand layer must necessarily be made thick to offer firm support for the pots when packed. The roof is then covered with loose soil as an insulator before the commencement of the firing. Fig. 11

3. <u>Termite mound (Anthill) downdraft kiln.</u>

With downdraft kilns, heat is introduced from the firebox and the flames are deflected upwards by a bag wall into the chamber, down through the pots and out through a flue at the floor to the chimney. This kiln has the advantage of firing more evenly since the flames are held in the chamber for a longer period.

Anthills are widely distributed all over the country and can be used as a viable structure for a down draft kiln in a school setting.

A reasonably large termite mound with a large circumference of over 30 feet and a height of about 7 feet at the apex is ideal for use as a kiln. It should have very little quantity of organic matter so a colour very close to laterite is better. In mounds that are 'alive' with soldier ants it is necessary to make a small hole near the top of the mound where some amount of liquid chemicals like D.D.T. or Elocron can be poured into the earth mound. After a few days, the ants will desert the mound to make scooping possible.

The body of the mound is usually not solid but honey combed with a labyrinth of passages of varying sizes within. The earth inside the mound should be scooped and put aside to make bricks for closing the doorway. Fig. 13

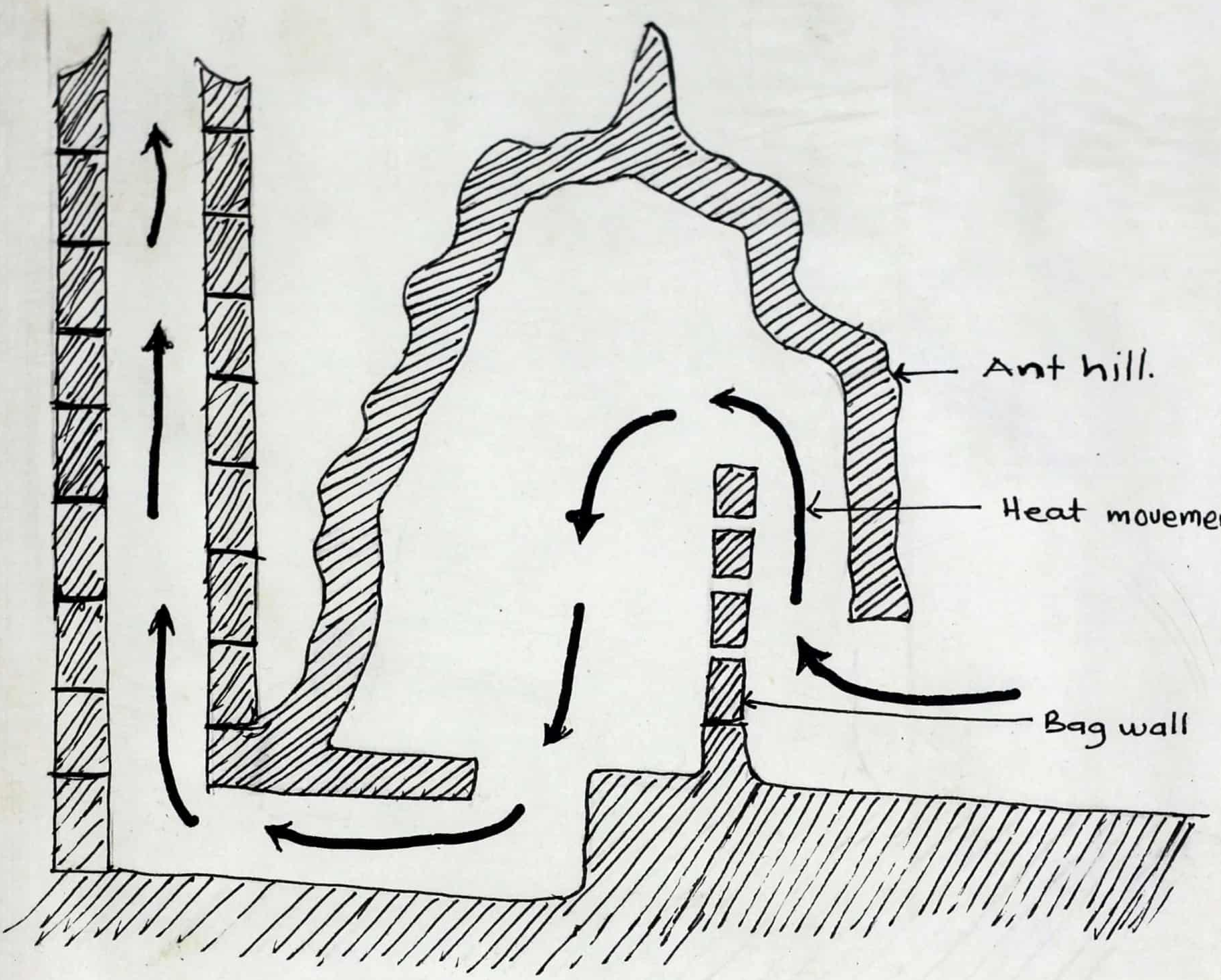


Fig.14 A termite mound kiln.

A flue of about 35 square centimetres in cross section made in the centre of the mound is enough for a reasonably large kiln.

The chimney can be formed by the use of bricks. Its height can be increased with galvanised sheet pipes or old metal buckets which can be held in position by the use of wooden supports. Fig.14

The ash pit is dug out of the ground, allowing a grate level low enough for the firebox to have a slight rise up to the bag wall. The fire box is constructed with bricks and the firebars are arranged at the grate level. The box is neatly roofed and covered with mud to make the sides and the top air tight.

A chequer must be built in the packing chamber before setting the kiln. When the kiln is full, the doorway is bricked up. These are removed after each firing and re-built after each packing.

The following procedure gives a very good firing result with few breakages.

1. Fill the empty kiln with fuel, set it ablaze and keep it going for several hours to heat up the chequer and chamber walls.

2. Fill the kiln with the dry pots (same day) when it has considerably cooled down. Leave overnight to allow pre-heating by the heated bricks and any remaining embers in the hearth.

3. Begin actual firing the following day.

The duration of the firing is determined by the size of the kiln and the amount of fuel used.

CHAPTER FOUR

SURFACE EFFECTS

With the advent of glazes, most schools seem to overlook the beauty and suitability of unglazed surfaces on red pottery wares. Many think that without modern kilns and glazes, school work cannot be given any good look. Different surface effects, which are colourful and decorative can be obtained by varying the firing methods or by giving the already fired wares a special treatment. Such treatments give to each ware a marked difference and significance.

Flames of varying intensity can transform basic elemental forms into uncommon objects of beauty. The fire imparts a range of colours by its irregular effect on the surface of the wares. Where flames impinge directly on the clay, the surface is apt to acquire a darker tone or even to fuse over.

In fuel burning firing, the atmosphere can be controlled to achieve varying and rich surface colour effects and textures.

Oxidizing firing

In an oxidizing fire, plenty of air is let into the fire to burn the fuel thoroughly. The flames therefore burn clearly with a predominantly blue colour and very little yellow flames. In the kiln, everything in the setting is sharply visible. The effect of this is the warm brown, reddish and orange colours that are produced after firing.

A complete oxidizing fire can be achieved if the ware is packed with spaces between them. Sufficient primary and secondary air should be allowed in to help burn the fuel. The stoking of the fire should be such that both primary and secondary air inlets are not choked. The chimney should be high enough to be able to draw in more air to burn the fuel effectively. A familiar example of an oxidizing flame is that of an ordinary lantern whose supply of oxygen through the air holes is sufficient to allow complete combustion. If however, the hand is placed over the air holes, the flames immediately become smoky. This same effect is noticed when the chimney is partly covered or if the air holes are blocked by embers.

Reduction firing

Reduction firing on the other hand is where there is insufficient oxygen available to consume the free carbon emanating from the heated clay, resulting in the formation of carbon monoxide. To reduce, the air supply should be cut back. Either the primary or the secondary air supply may be diminished or both may be cut back until the flames turn yellow. The chimney should be partly closed until a back pressure develops in the kiln. This will be evidenced by some flames coming out of the fire port and spy holes.

Kilns can be reduced by adding excess of fuel to the fire. Since the process involves an excess of unburnt carbon in the firing chamber, too much reduction is a waste of fuel. Heavy reduction will usually halt the advance of temperature or even cause a loss of temperature. It is better to alternate overstoking with light stoking so as to bring about temperature rise.

The effect of reduction on the appearance of a clay piece is a grey or black colour resulting from carbon deposited in the pores of the wares during firing and remaining there in the finished product. In reduction firing, changes occur in the iron contained in the clay and the iron oxide which is to some extent present in all clays, turns from brown or tan to grey or black. Different combinating proportions of iron to oxygen has a characteristic colour as follows.[1]

Ferric Iron ($Fe_2 O_3$) - Red

Ferrous Ferric ($Fe_3 - O_4$) - Yellow

Ferrous Iron ($Fe O$) - Black

Most iron compounds in nature are in the form of red iron oxide which is the most stable combination. In reduction firing, the iron oxide tends toward the ferrous state or black iron oxide which accounts for the characteristic black or grey colour of clays.

The open bonfire method of firing is to some extend and oxidising process so most of the wares turn brown with a few attaining a mottled surface. If black pots are desired, a second reduction firing ought to be done. The smoke that emanates from a reducing fire seals the pores of the pots and gives them a glossy finish.

After bonfire firing the red hot pots are removed from the dying fire with a long, wooden pole into a heap of either fresh cocoa leaves or grass or wood shavings. The rubbish is likely to be ignited and if it does, the flames should be beaten down. If jet black pots are desired, the pot can be left in the heap for a longer

1. Daniel Rhodes, Clay and Glazes Pg.264, Pitman 1973

time to allow a film of tar (from the leaves) to collect on the ware. If, however, a black and brown mottled effect is desired, about three minutes of smoking is enough.

The same effect can be achieved by piling the baked pots in a hole from which smoke emanates. Fig. 15.

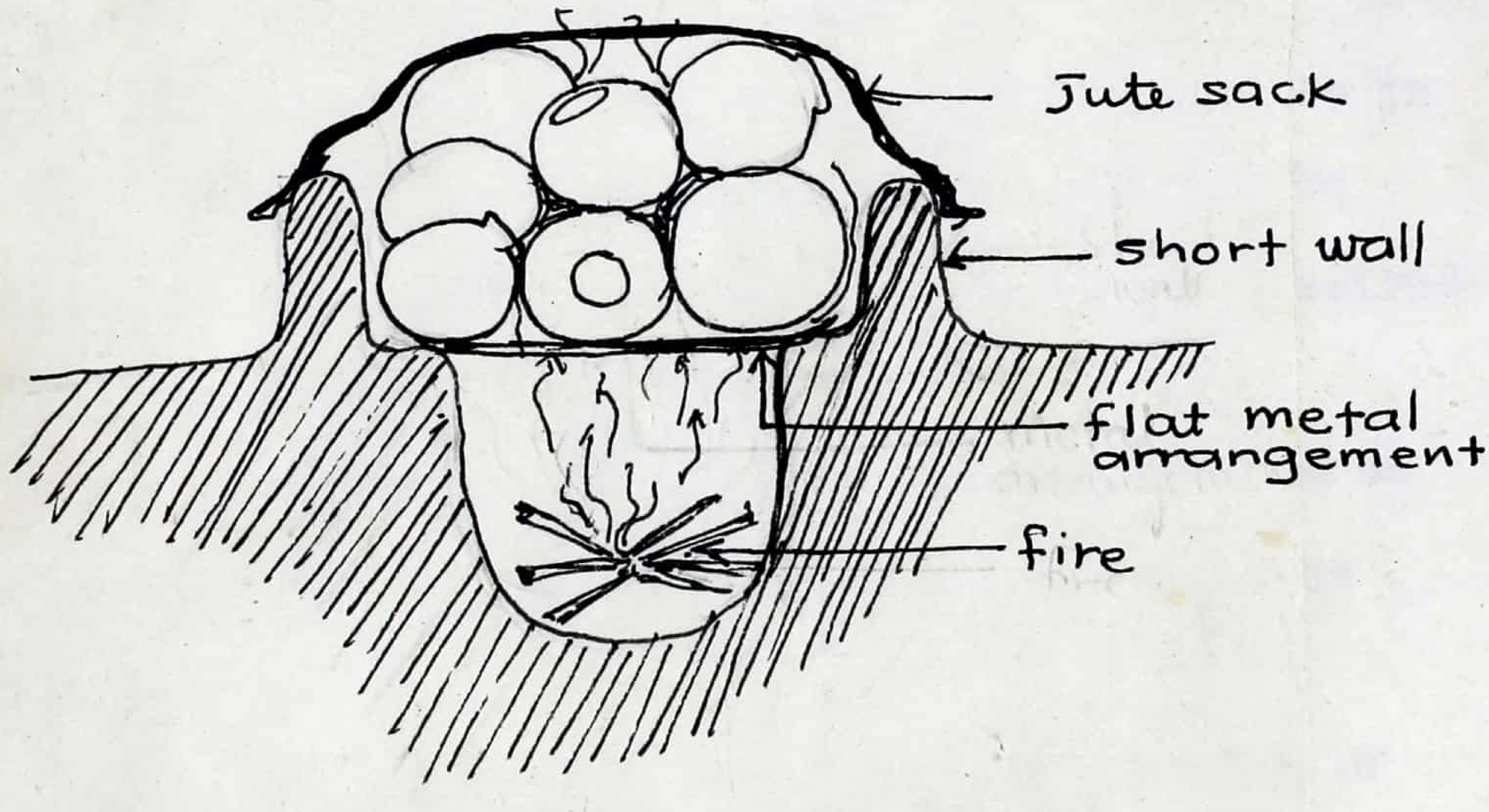


Fig. 15 Smoking of pottery wares.

The hole should be about 75cm deep with a diameter of between 60cm and 90cm. A short swish wall of about 8 inches high can be built around the hole (about six inches from its edge). On the floor of this hole, kindling wood should be arranged and live charcoal poured over.

As the smoke is liberated, corn cobs, cassava peels, green leaves and other moist materials can be heaped on the fire thus kindled. Old cutlass or flat metals should be arranged in a net pattern over the hole as the smoke intensifies and the fired pots quickly assembled on the net for smoking.

Wet jute sacks can be used to cover the pots in order to reduce the loss of smoke which should be allowed to circulate round the pots until the desired result is achieved.

The duration of the smoking process depends on the desired effect as well as the amount of smoke emitted.

Closely packed wares can have some patches of red or brown at places where the pots touch each other.

Very beautiful surface effects can also be achieved by re-firing bisque wares using moist sawdust. This result in dark coloured effects. Mottled effects can also result from packing with little sawdust. In each case, the cairn of bricks should have some spaces in order to admit just enough air for the burning of the moist sawdust.

Another way is to build a cairn of bricks around the wares allowing spaces for crumpled newspapers and dried grass to be packed between the wares and the bricks. As the course of bricks rise around the pots the newspapers are added at each level. At the top the brick arrangement is covered with bricks or a flat metal sheet. The papers are ignited through the spaces between the bricks. As the paper burns it liberates a great deal of smoke and in about five to ten minutes the smoking is over. Fig. 16

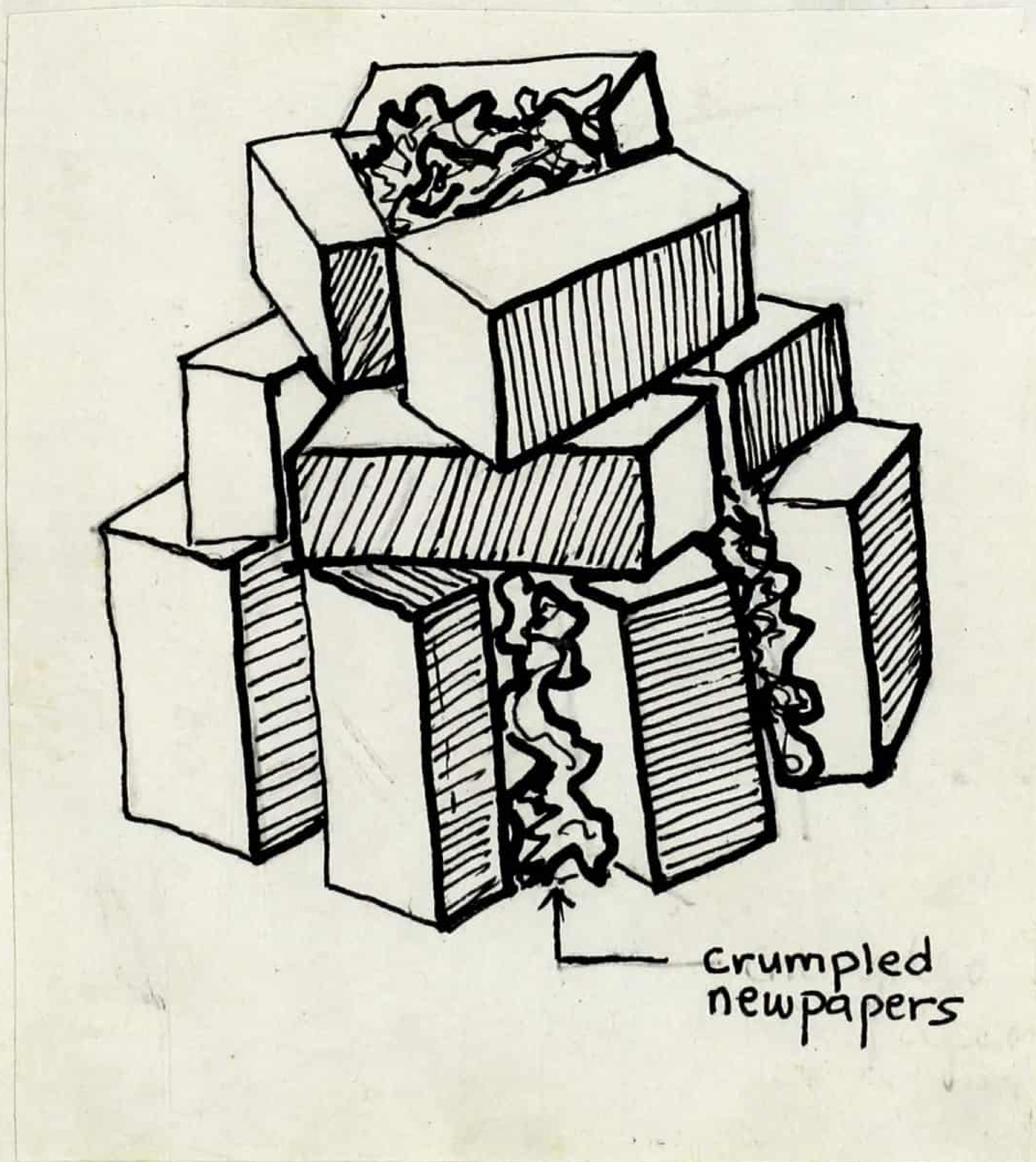


Fig. 16 Firing with crumpled newspapers.

Interesting localised reduction or carbonisation effects can be controlled to some extend by the careful arrangement of crumpled papers when stacking the cairn.

Another kind of surface modulation which does not involve glazes is the staining or coloration caused by both organic and inorganic materials fired with the clay wares in a sagger. This method of firing can be done with any kiln that can fire to about 1,000^{o}C or less. For this firing, saggers are constructed in a kiln not as a protective cover against direct flame impingement but as an enclosure within which the effects of fire are encouraged and courted by packing a variety of organic matter around the pots. Instead of thrown saggers which break easily, brick saggers can be built around the wares. Fig. 17.

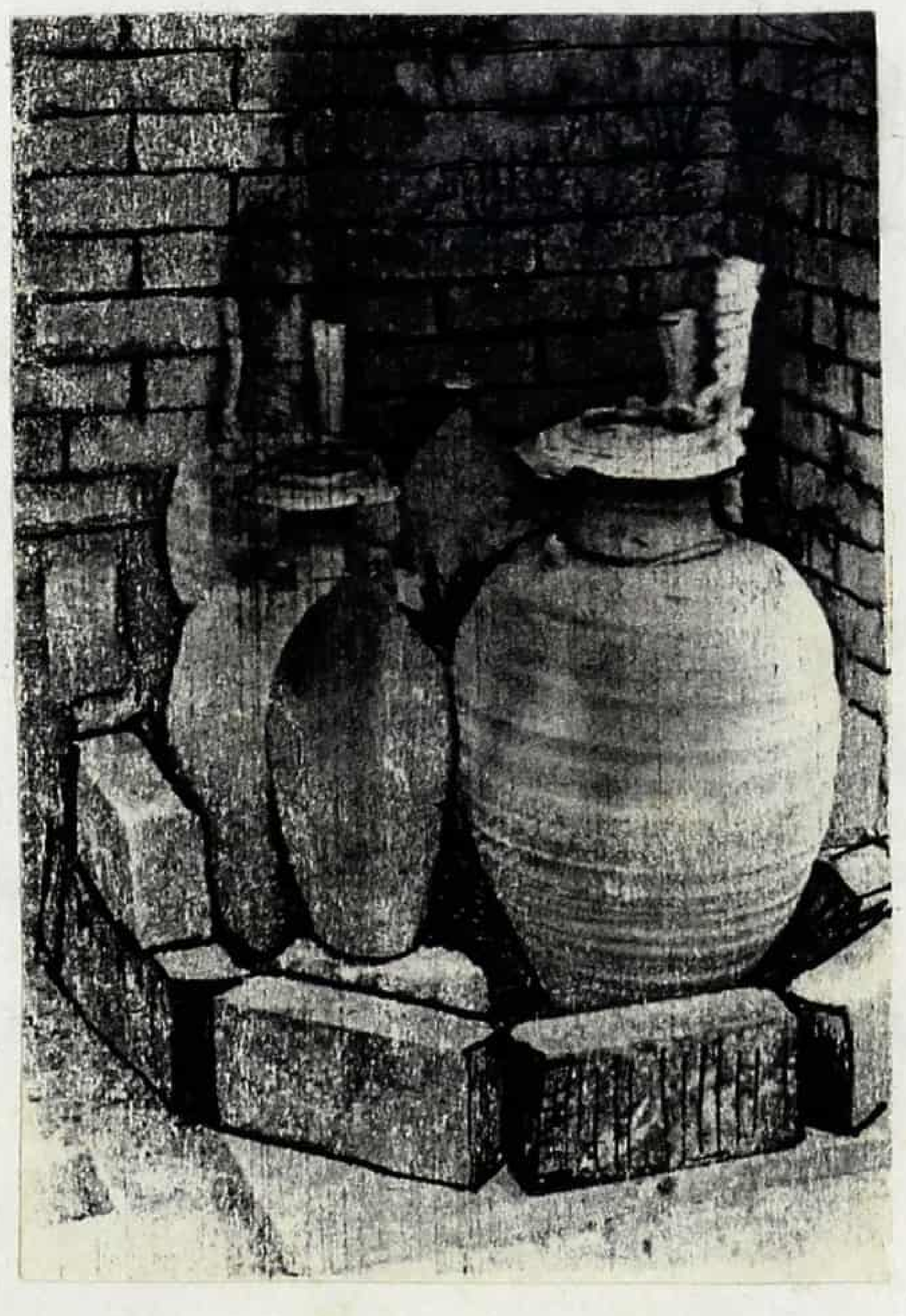


Fig.17 Building a brick sagger around ware.

Brick saggers can be built by placing two or three courses of bricks on their 9 inch edges to form an interlocking wall. Where there is a problem with levelling sand and dry clay can be used to level them up.

Pots are then placed on the floor of the kiln or elevated on bricks. There should be some space around the pots so that they are touched by the organic matter on all sides. The packing of materials around the pots and building of the sagger can be done simultaneously.

Materials for saggers

The choice of materials for stuffing the saggers to a great extent determines the final results. Wood charcoal contributes strong dark shades while increasing the temperature of the sagger. It also produces subtle markings on the pots.

Broken soft bricks act as a masking material and creates openness in the kiln which encourages flashing as the flame moves through the sagger. Seaweed contributes salt which leaves raised textural markings, while sawdust and wood shavings are valuable marking agents when soaked in salt water. Rice hulls, chaff and straw where available can be used, while fruits,banana and cassava peelings and similar materials can give very effective results. These will give better results when soaked in brine provided they are thoroughly dry prior to setting the saggers.

Salt (Sodium Chloride) is the principal influencer of colour when a small quantity is sprinkled on and around the pots at various levels during sagger construction. At high temperatures salt releases some deadly chlorine gases so salts should be introduced only where the kiln is located in an open place where enough air circulates.

To achieve a good setting of materials they should be evenly spaced and layered so as to create a unified packing which will prevent blank spots on the pots. A balance of dark and light areas can be achieved by even distribution of non carbonaceous or masking materials and the carbonaceous ones. There should be concern for all visible surfaces. This means packing the interior or the neck of a pot with the same care used for the packing of the outside.

In a kiln with inadequate space as in the trench kiln, the materials can still be set to produce prominent mottling spots, streaks or flashes without saggers.

There is no limit to the materials which may be tried for the smoking effect. Cassava flour for example can be painted or trailed over a pot to give prominent brown markings. If straw or weeds are used, they may be dipped first in light salt solution and prominent marks will be noticed. Fig.18.

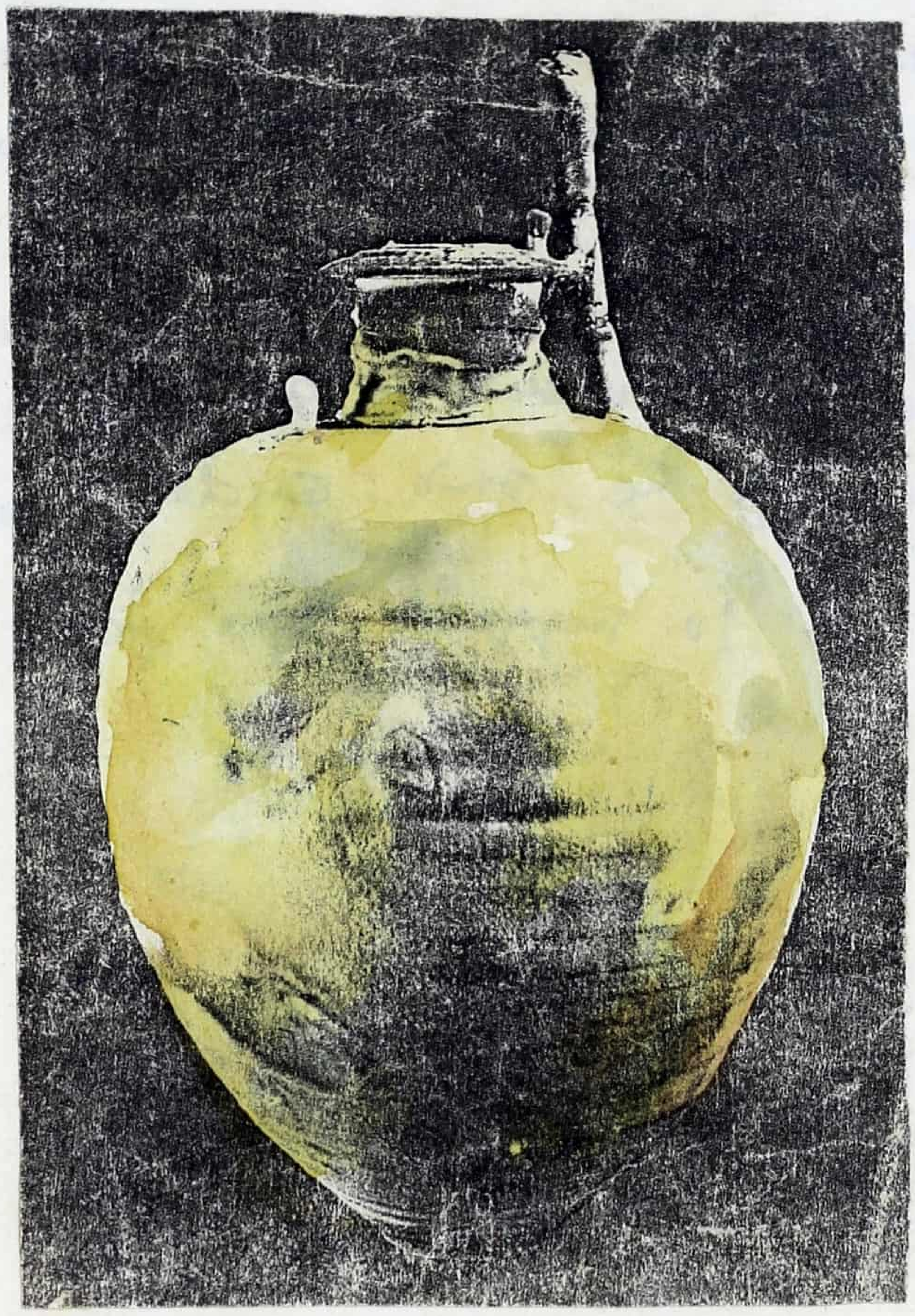


Fig.18 Surface effect from wood firing.

Apart from the processes which are achieved through conscious control, pots fired in wood fired kilns may be partially glazed in the fire by a deposit of ash. The way-ward and unexpected character of such partial glazing can sometimes give to a pot the quality of a natural event different from a planned effect. Certainly, the varied surfaces which can result from such firings are often interesting and seem to be close to the form in a way that man-made decorations cannot produce.

CHAPTER FIVE

CONCLUSION

Clay, until it is fired and made durable is a material of little or no practical value. The sundried brick, although an exception cannot be compared to a fired brick which when fired to red heat becomes a hard and permanent substance. After firing, the material which was once soft and crumbles easily, becomes hard and impevious to water.

Preparation for successful firing begin during clay moulding. The clay must be wedged thoroughly to remove undesirable air pockets and possible lumpiness, joints properly sealed and ware bone dry.

The drying of clay is always accompanied by shrinkage. As the film of water between the clay particles is drawn off by evaporation the particles draw closer together to close up the interstices. The effect of this action is the shrinkage of the entire mass of clay.

Drying shrinkage however, depends on particle size and the amount of water which seperates them.

Clay with fine particles shrink more than those of large particle size.

Drying in clay is greatly facilitated by the presence of non-plastics such as sand or grog. These tend to take up less water than clay and therefore dries out more readily. These non-plastic materials also open up the pores or channels through which moisture can escape toward the surface. Clays which contain a large percentage of non-clay particles are called 'open bodies'

In the making of ceramic sculptures and terra cotta pieces, open clay bodies are necessary. Apart from the quick drying they promote the particles serve as skeletons to hold the object in shape during drying and firing. Wares made with open bodies shrink and distort very little when subjected to heat. In schools, grog can ordinarily be used for this purpose. Sand serves the same purpose too. However, clays prepared for throwing should have very little non-plastic content.

If warping, cracking or deformation is to be avoided, objects made of plastic clay must be dried slowly and evenly. If one part of the clay object dries faster than the other the unequal shrinkage between them may cause warping and cracking. This is very common in objects with uneven walls and wares dried directly in the sunshine.

In schools students' works should be dried in the art room under room temperature. If quick drying becomes necessary all parts of the piece should receive equal amounts of air.

Dried clay bodies vary greatly in strength. An object made from very plastic clay with fine particle size may be stronger when dried than clay with a high percentage of non-plastics. In the handling of dry wares for firing, care must be taken to prevent breakages.

Although a clay ware may be well dried, it may contain some amount of moisture absorbed from the atmosphere. Firing completes the drying process in clay wares so it must be brought about slowly otherwise the formation of steam within the clay body may cause it to explode. No matter how dry a clay piece may be the chemically combined water of crystalization ought to be driven off.

This water which forms part of the molecular structure of the clay is unaffected by temperature below 350°C[2]. Forming about 14% of the total weight of the clay, the expulsion of this inherent moisture causes voids in the structure. Firing must necessarily be slow at the beginning and prolonged to prevent sudden evolution of steam and possible breaking of the object.

For large kilns several hours are needed for water smoking. School kilns must not be too large in order to limit the firing period to suit the school time table. A shift system can be adopted to attend to the kiln but if all students can be present from the beginning of the firing to its completion, the better it will be.

For kilns of between 30 and 60 centimetres internal diameter, three to five hours is sufficient for firing small and light wares. The first stage of firing should be dead slow with a couple of pieces of wood five to eight centimetres diameter at a time. The second stage should make use of three or four five to eight centimetre wood pieces for fuel. In the third and final stage all moisture in the kiln and pots ought to be eliminated.

The stoke can be increased to six pieces,

2. Rhodes Daniel, Clay and Glazes Pg.16 Pitman 1973

roughly 3 centimetres in diameter crisscrossing all to ensure good combustion. It is during this part of the firing that explosions may occur. If this should happen the stoking ought to be slowed down for at least half an hour. In the final quater, more wood can be used by the thinner they are the better. It is advisable to allow more time for the first half of firing because thicke cone walled wares may need a longer time to expel its water of crystalization.

In schools where pyrometers and cones are not available, the inside colour of the kiln can be used as an excellent indicator of its temperature as indicated on the table below[3].

Colour	Degrees Centigrade
Low visible red	475°
Low visible red to dark red	475° - 650°
Dark red to cherry red	650° - 750°
Cherry red to bright cherry red	750° - 815°
Bright cherry red to Orange	815° - 900°
Orange to Yellow	900° -1090°
Yellow to light Yellow	1090° -1315°
Light Yellow to White	1315° -1540°

Colour scale for temperatures

3. Rhodes Daniel, Kilns, Design & Construction Pitman U.K. 1968

Draw trials can also be used as temperature indicators. Small trials sometimes shaped like rings can be set up at the spy hole. They should be made of the same clay used for modelling of the wares being fired. As the firing nears completion, the rings are hooked out with an iron rod, cooled in water and examined to find out if the clay has had sufficient heating. Several trials may be drawn out at intervals to find out conditions in the kiln.

If the trials indicate maturity of wares the firing can be stopped, the fire mouth closed and all cracks thoroughly basted with a 50 - 50 mixture of sand and mud to prevent cold air from entering and dunting the wares.

Kiln attendance is very tiresome and exhausting so students should be advised to keep a distance away from the kiln except when stoking or attracted by an unusual thing in the kiln. There should be enough water around to quench the fire that is taken out of the kiln after raking.

As firing temperature increases the crystals of quartz (usually associated with the clay in nature as an accessory material) re-arrange themselves into a slightly different order. Thus when 573°C is reached, quartz crystals undergo a change known as the change from alpha to beta quartz. When cooling the beta quartz changes back to alpha. These changes are accompanied by slight changes in volume so in order to avoid damages to clay objects, the volume changes must be made to take place slowly. In the firing and cooling of any clay object, gradual heating and gradual cooling is necessary at the critical temperature (573°C) in order to prevent cracking. Any unequal expansion and contraction of a clay object can result in damaging the object.

Vitrification, another form of change that is noticed in clay as it is heated is the hardening, tightening and partial glassification of clay. Usually associated with shrinkage, it gives clay its characteristic hard, durable, dense and rock-like properties. This hardness results from fusions or melting of some of the components of the clay, particularly impurities such as iron oxide. As the clay is subjected to heat, the more fusible impurities of the clay may melt and soak into the surrounding area, binding the particles together like a glue and acting as a solvent in promoting further fusion.

Clays vitrify at different temperatures depending on their composition. A common red clay rich in iron and other mineral impurities may fire to hardness at about 1000°C and may melt to a liquid at about 1,250°C.

Successful firing of clay to high temperature therefore depends on understanding the basic characteristics of the clay.

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