OMAN

The problems and potentials of the indigenous built environment in a developing country.

Allan Cain . Farroukh Afshar . John Norton

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The problems and potentials of the indigenous built environment in a developing country

DEVELOPMENT WORKSHOP
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Preface

In the spring of 1973 we went to Egypt to do research into its indigenous building and planning methods. Part of our work consisted of assessing certain experimental houses in Cairo and a village in Gourna, Luxor, which had been built on traditional design principles. These had been designed and built by Professor Hassan Fathy. Shortly afterwards Professor Fathy, as consultant on Rural Development ta the Sultanate of Oman, proposed that a similar study be carried out in Oman. This was accepted and we were invited by the government ta do a study of certain traditional buildings and assess what could be learnt from them for application in new building projects. While fulfilling this brief we also had the opportunity to carry out for our own research the extended study presented here. The material covering the original brief has been incorporated within this study.

After a month of preparatory work in London and Egypt with Professor Fathy, we arrived in Oman in the first week of September. We were there as a team until the first week in November, and two of us stayed on to work there for a further three weeks. The period was one of intense work and travel. We had the use of a land-rover. An English speaking Omani, Abdulla Hamadani, joined us to drive and interpret. Language was not a problem to the extent we had anticipated, since one of us knew Urdu and Persian which are spoken along the Northern Coastal Plain, and another spoke Arabie, the national language of Oman.

During our stay in Oman we visited and stayed in some twenty towns and villages in six of the eight major areas of the country. Of the two we omitted, one was the desert interior which has very few settlements, and the other, in the Dhofar Hills of the Salala hinterland, was a guerrilla war zone. We would spend approximately ten days in a major settlement in any one area, during which time we would travel to neighbouring villages if there was something of particular relevance to our study. We also were able to visit Dubai, one of the neighbouring towns in the United Arab Emirates, where the old town provides a good example of indigenous urbén forms in this part of the world. Not until recently have efforts been made to collate and publish information on Oman in any comprehensive fashion. For each area we visited, therefore, we first tried to understand its physical and economic base: the major occupations of its inhabitants and how these were changing, and how these factors affected the distribution and pattern of the settlements and house forms in the area.

We followed a similar approach in enquiring into the social relationships between the people as a whole and within the family structure. The time factor limited this line of enquiry to some extent, but it was nevertheless of great value in establishing what developed into more than just a contextual framework for our more detailed work. More often than not there were no climatic records available but we were technically well equipped in this respect. We had a comprehensive set of equipment which enahled us to make a climatic profile for each area we visited.This was sometimes augmented by any further information we could obtain from local people, or in certain areas from military bases which had kept records. Details of our findings on the subject appear in the climatic section of the report.

In each area, we had first to contact the local Wali (Mayor), and explain to him what we were doing. Through him we would gain access to the people in his area. The two groups on which our interest centred were the local craftsmen and builders, and the families of the houses we studied. From the craftsmen and builders we learned the construction methods of the area and their views on the changes that are taking place, particularly how they are affecting the built environment and themselves professionally. From the families we learned how the house and its rooms related to their needs, the family structure, at what stages they had built their houses; why in every case they had been built over a period of time, and were still being modified; what they liked about them and what improvements they would like to see brought about. ·

We developed a basic questionaire, which functioned more usefully as a check- list to ensure that we adequately covered the basic information we needed. Inevitably during the days we were in an area, conversation ranged beyond this, giving us a better understanding of the people and the area as a whole.

It would be impossible to list the very many people who were so helpful and hospitable throughout our stay, and to whom we owe our gratitude. Our particular thanks go to Professor Fathy, whose pioneering work remains a source of inspiration to us: to Mr J Townsend, Economie Advisor to the Government of Oman, to H.E. Karim el Harmy, Minister for Development, to their respective staffs, to the Dhofar Development Organisation, and the Petroleum Development Organisation. Additional thanks to Habib the barasti builder and Abdulla our constant companion. Our thanks to Laura Pinter for the many hours she spent typing the manuscript.

The fourth member of our team, Omar el Farouk was unable to contribute beyond the initial field-work. We owe him special thanks for his invaluable assistance during this stage.

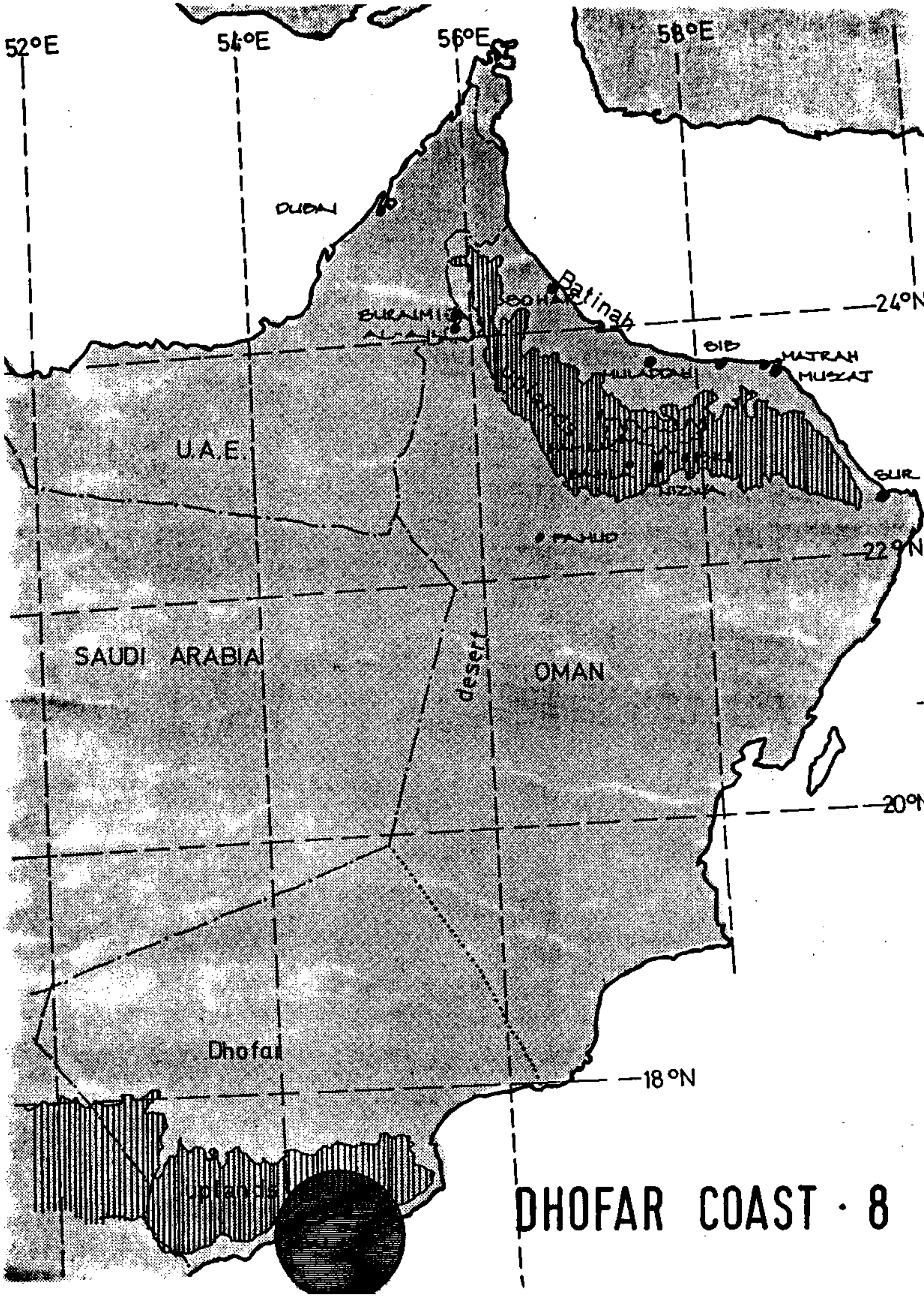
The information from the field-work was collated and this study prepared and written by the three of us, for which we take full responsibility.

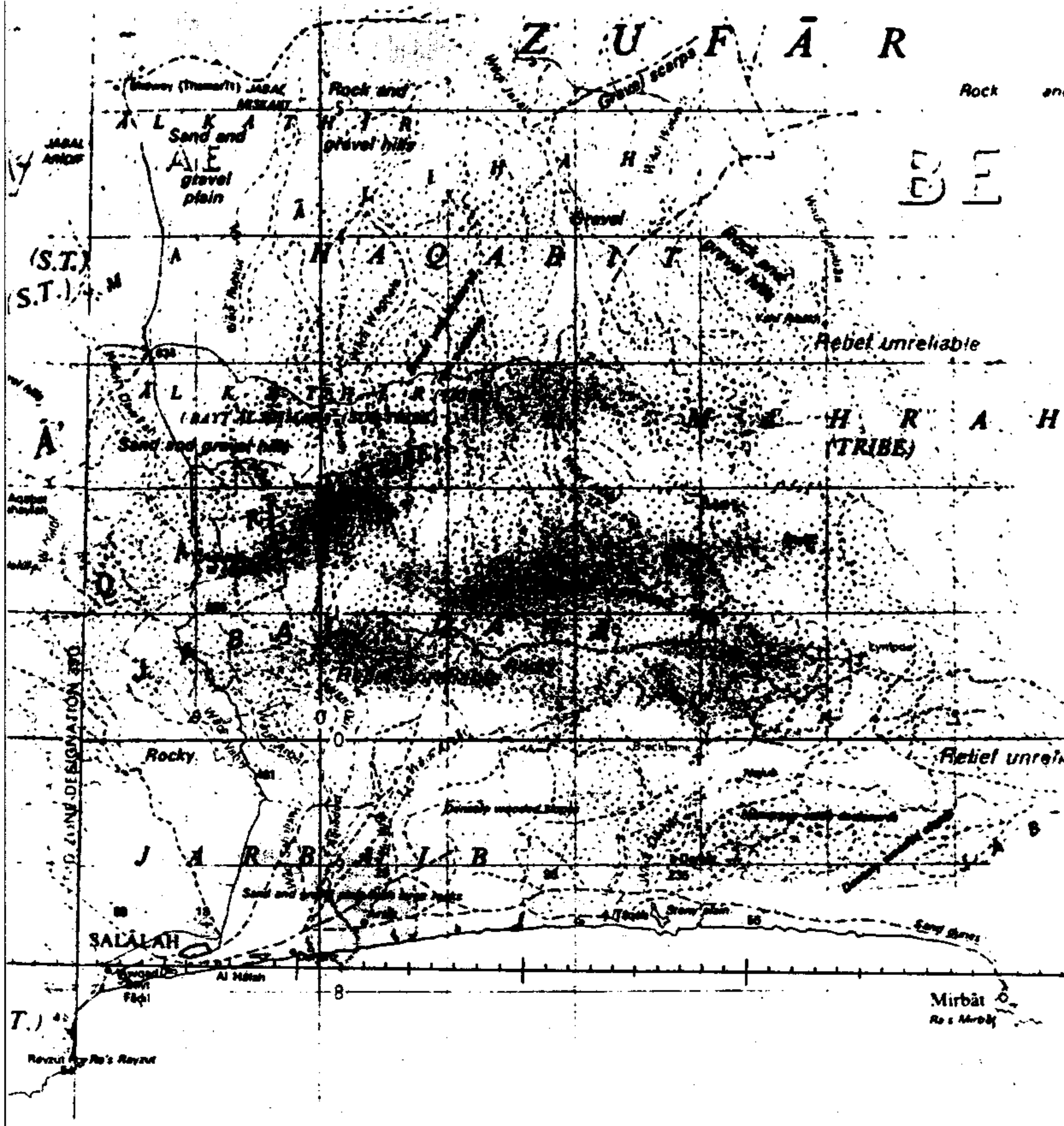
Allan Cain

Farroukh Afshar

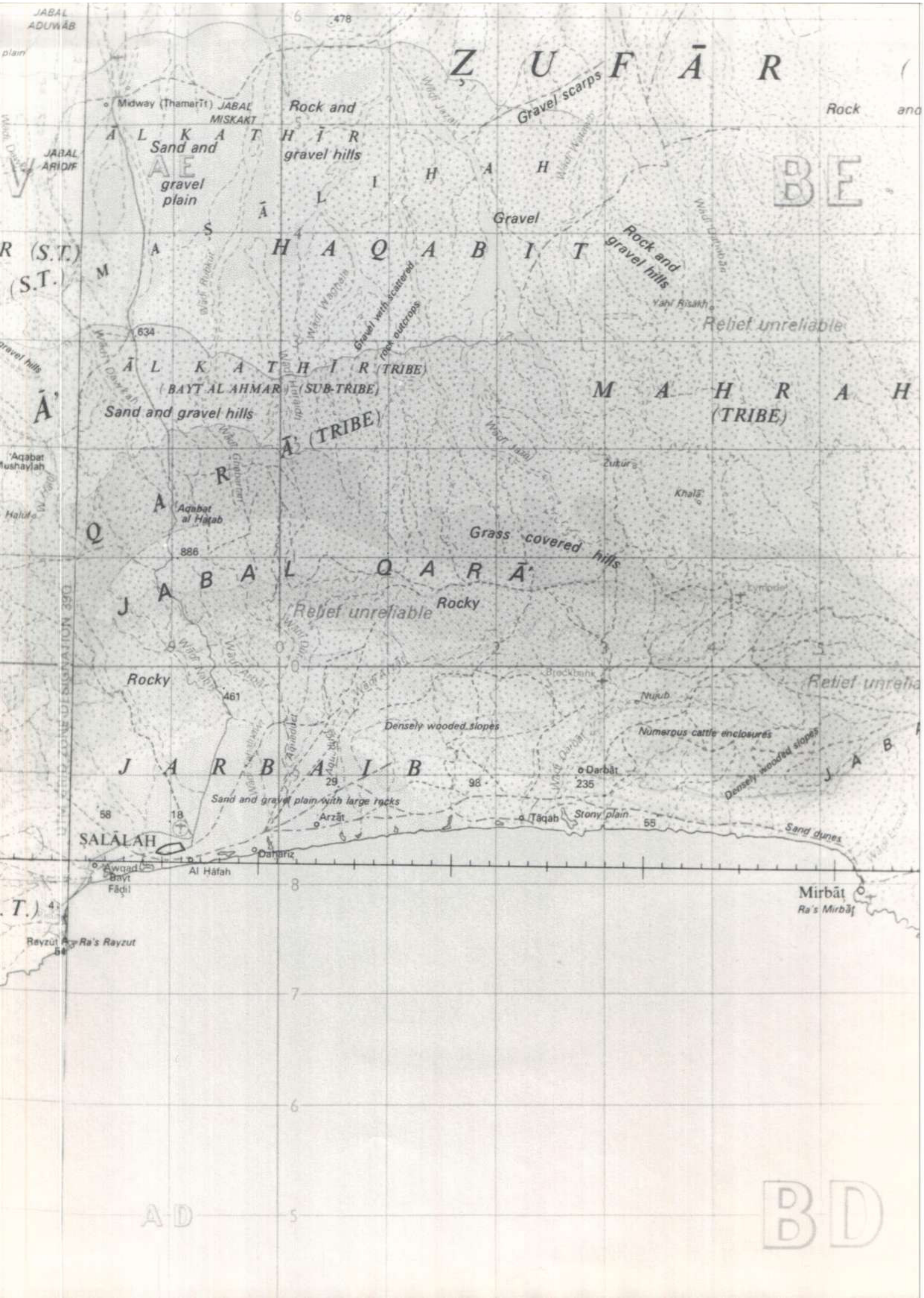
John Norton

DHOFAR COAST · 8





8 Dhofar Coastal Plain



JABAL ADUWĀB
ZUFĀR
Midway (Thamarīt)
JABAL MISKAKT
Rock and gravel hills
Gravel scarps
Wādī Jazal
Rock and
ĀL KATHĪR
Sand and gravel plain
JABAL ARIDIF
ĀL IHAH
Gravel
AE
BE
AṢ ṢAHAQ
R (S.T.)
(S.T.)
HAQABIT
Rock and gravel hills
Wādī Ghadun
Wādī Rufkut
Wādī Waqhain
Gravel with scattered rock outcrops
Yahl Risakh
Relief unreliable
634
gravel hills
Wādī Dawkah
ĀL KATHĪR (TRIBE)
BAYT AL AHMAR (SUB-TRIBE)
Sand and gravel hills
Ā'
QARĀ' (TRIBE)
MAHRAH (TRIBE)
Wādī Haradi
Wādī Jabal
'Aqabat Mushaylah
Zutur
Khalā
Halufo
W. Halif
Wādī Ghadhawri
Aqabat al Hatab
886
Grass covered hills
JABAL QARĀ'
Rocky
Relief unreliable
UNIVERSAL GRID ZONE DESIGNATION 39Q
Wādī Dahr
Wādī Naḥīz
Wādī Arzat
Rocky
461
Brockbank
Nujub
Relief unrelia
Densely wooded slopes
Numerous cattle enclosures
Densely wooded slopes
Wādī Darbāt
JARBAIB
Darbāt
235
98
29
Sand and gravel plain with large rocks
Arzāt
Tāqah
Stony plain
55
Sand dunes
58
18
SALĀLAH
Dahariz
'Awqad
Bayt Fāḍil
Al Hāfah
Mirbāt
Ra's Mirbāṭ
(S.T.)
Rayzūt
Ra's Rayzut
54
AD
BD

8.1. Introduction

8.1.1 Physical Description

The Dofar coastal plain, stretching along the southern shoreline, is widest between Rayzut and Salala (4 to 5 km) and tapers to a narrow stretch between "Taqah and Hirbat to the east. The rocky hills and mountains behind rise to almost 1500 metres. The coastal plain is predominantly a limestone shelf with only a thin layer of fertile soil. While planting along the coast is mainly palm groves, which were at one time supported by a sophisticated irrigation (falaj) system, agriculture in general has been in decline in recent years. The southern slopes of the jebal are green with grasses and small trees during and after the rainy season.

Salala lies just inland on the Dofar coast, facing the Indian Ocean, with its back to the hills and mountains of the interior. Salala's physical isolation and its present political situation - i.e. with guerrillas active in the hills - has tended to create many development problems.

8.1.2 Social-Economic Situation

Even though Salala presently finds itself isolated; historically there existed strong ties between the town and the people of the interior. The economy of Salala was dependant upon its coconut plantations and its fishing industry. Sardine fishing though declining now still employs about 1/5 of the working population of Dofar. I

Traditionally a greater part of the Salala population was involved with some aspect of fishing or processing in the winter sardine season. A large catch was taken then composted and dried on the beach. Oil was collected and exported to the Gulf or used as a wood preservative, (water proofer) and the dried residue was either used for agricultural fertilizer on the coast or sold as cattle fodder in the interior.

The people of the interior (Jebbelese) are herdsmen, grazing their cattle on the grassy slopes for most of the year. In the dry season, before the monsoon when the hills were bare of vegetation, the herdsmen would rely on dry sardines to feed the cattle. This was one of the basis for trade between the hills and the coast. Cattle were traded for sardines and other basic commodities required in the mountains and interior villages.

The war has of course cut off the trade which was basic to both the cattle raising and sardine fishing industries and both the Jebbelese and the inhabitants have suffered because of it.

I Whitehead Report

Salala has become to a large extent dependant.upon imports. Local inhabitants tend to be employed by expatriate companies or the central government. Small scale agriculture is in decline, although several foreign firms are beginning to develop large industriallzed farms. The cattle herding system has been largely disrupted by the war.

The influx of refugees into the Salala.area has resulted in a great demand for land, causing severe planning problems, and an over taxation on building material resources. On the other hand this sudden increase in population has stimulated the building construction industry. Building tradesmen and craftsmen have come in to Salala from India and Pakistan because of the demand. These people along with large Expatriate Contracting Companies bring with them western developed ideas and construction techniques, not always in tune with Salala's particular needs.

8.1.3 Salala

Climate:

Salala technically lies in the Warm Humid Tropical Zone, and is often said to be in the monsoonal area of influence.

"Monsoon is a misleading description as it has little in common with the weather pattern of this name that effects India. It seems likely that stronger southerly winds that start in May cause cool water to be drawn to the surface of the sea and this lowering of temperature results in an almost saturated air. This cool damp air moves up over the Jebel as a thick mist which rapidly dissipates as it passes over the mountains. The area which benefits from this mist is clearly defined by the belt of vegetation along the coast." 1.

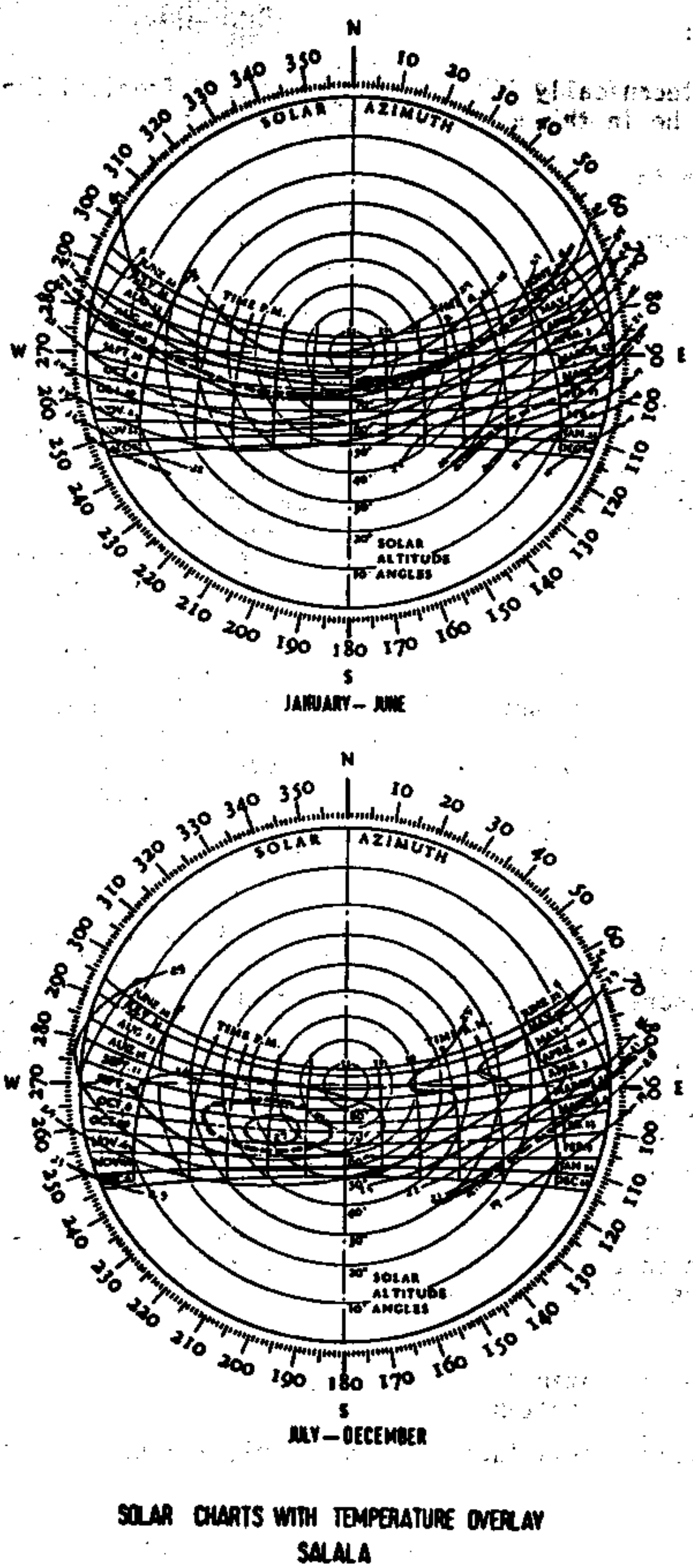
Salala is an area of relatively moderate humidity for most of the year, but during the summer very high for the above reason. The so-called summer monsoonal season is not a season of rain i.e. but one of mist and a slight drizzle, the humidity averaging 95 percent in July and August. The area in fact receives very little rain with a total of only 25mm in each of those months and a yearly total of only 80m on an average. 2.

Concerning thermal comfort, critical times of the year found to be too hot are May and June and again for parts of October. The months ,of July and August, though uncomfortable due to the high humidity are relatively lower temperatures because of the moderating affect of the moist onshore winds. In the winter months the temperatures are found to be relatively cool, lying outside the comfort zone, in the mornings, evenings and night time.

The Salala coastal plain is subject throughout most of the year to the localized condition of daily onshore-offshore winds. the mechanics of which have been explained earlier (ref - Batinah Coast). Daytime winds are onshore from the south and northerly night time winds are from the hills. This general pattern is modified by seasonal .shifts in the prevailing wind pattern providing a generally dominant southerly wind in the summer and a northerly condition in the winter. For 15 to 20 days in the winter highly destructive dry cold winds tend to occur. These gale force winds carrying sand and dust can damage crops and built structures.

Figures 81 and 82 give detailed information on Salala's climate. Refer to section 2 - Climatic Introduction - for a description of how to read and make use of these charts.

1. Land and Water Resource survey - Inception Report Dhofar Development - Halcrow Consultants.
2. Meteorological Tables for the World - H.M.S.O. Part V, p.84.

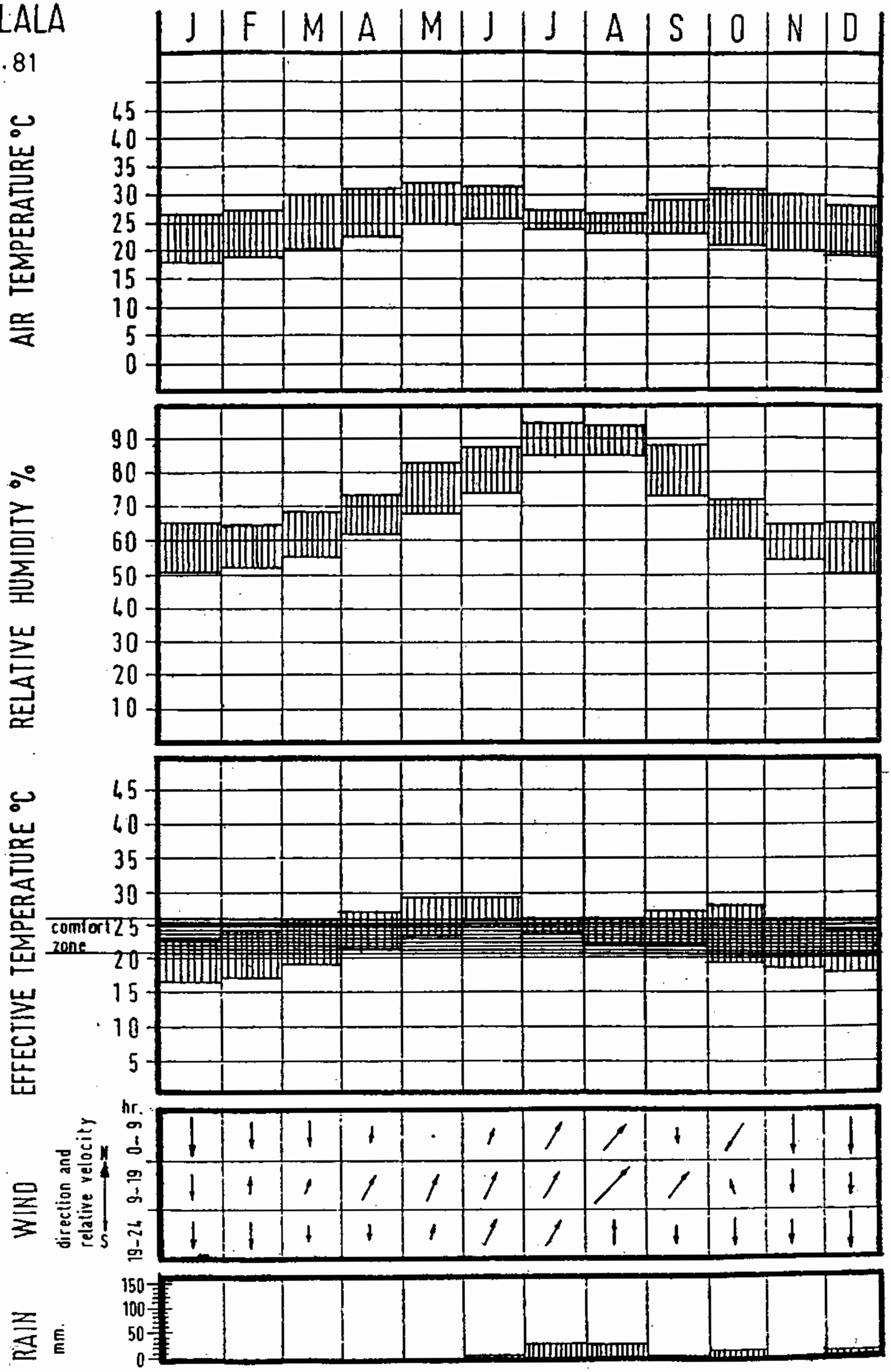


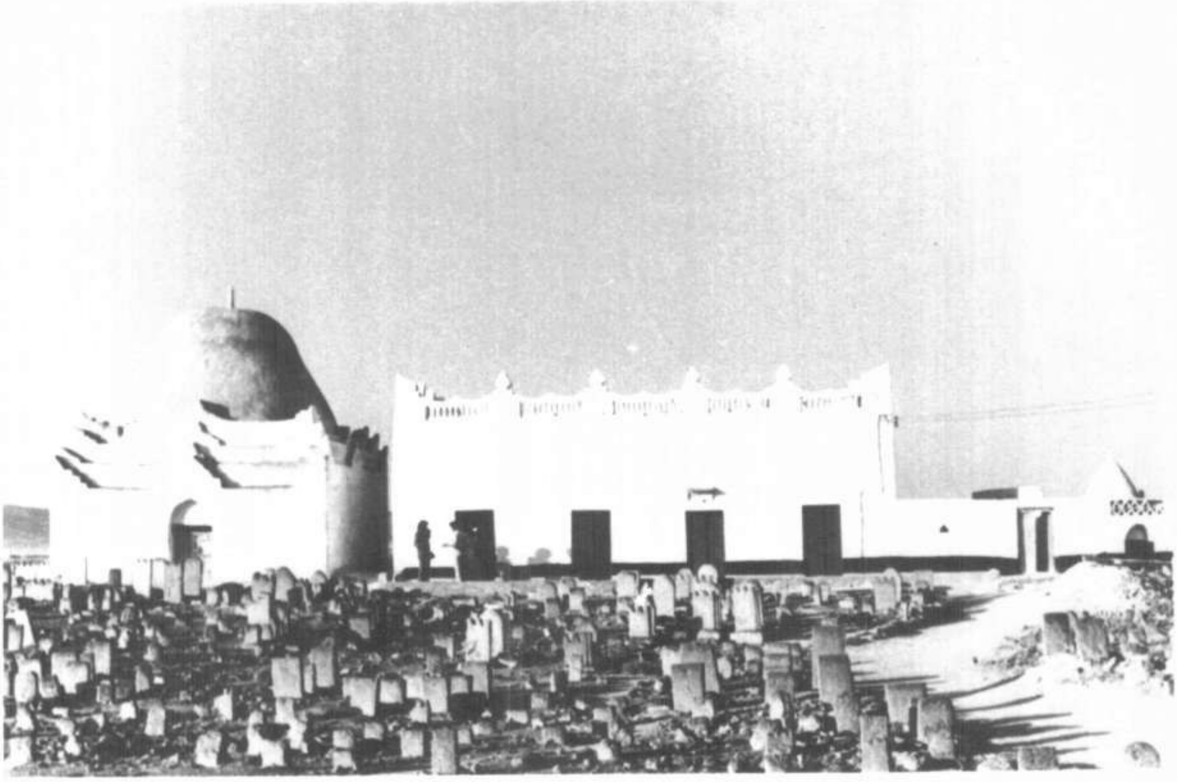
SOLAR CHARTS WITH TEMPERATURE OVERLAY
SALALA

Fig. 82

SALALA

Fig. 81





The high quality of the indiginous architecture of the Salala region can be seen in its Mosques.

One of the oldest town houses in Salala (18'th century), though in disrepair.

8.1.4 Materials Introduction

Limestone is the'most common indigenous material used in the construction of permanent buildings in Salala, while barasti is used extensively in less substantial and cheaper construction. Limestone buildings are still standing which are said to be 200 years old or more. Because of the reusability of the material it is quite likely that there are sections: of buildings or at least material being used now which are much older.

Limestone is still the standard building material used today in Salala even though the costs have risen astronomically in the last few years. Because of the political and military situation effecting the access to particular materials some building techniques have been altered. But in general, when the owners or local builders construct a house it follows in many ways the design and social functional layout of past builders, except for certain details. On the other hand it is now apparent that living patterns of the west and the use of non-indigenous materials, 'furnishings and implements are beginning to influence the use of many buildings. This may result in the change in house form in the near future.

It is true that imported materials such as cement for block making are beginning to be used in home building in Salala, especially in govern- , ment projects. The price is 22 Rials/100 rather than 30 Rials/100 for limestone block. However cement block has several disadvantages when compared with limestone.

1) It is thermally inferior in its response to climatic conditions (to be discussed later).
2) It is not reusable as is limestone block.
3) Its price depends on world market fluctuations and because of shortages is continually increasing in price.
4) The capital invested in an imported material is lost to the community, where capital invested in limestone goes to increase the buying power of local people and keeps the money circulating in the community.

Concrete blocks do have the advantage of being a regular size and can be handled more easily in the construction process.

Coconut palm frond stem (barasti) construction is quite widely used especially along the beach front. It is of course the cheapest comonly used material in the area, and relatively simple structures are made using it. The lowest social group tends to live in barasti houses. More sophisticated houses of barasti and mud plaster are found inland.

Fig. 83 SETTLEMENT PATTERNS SALALA

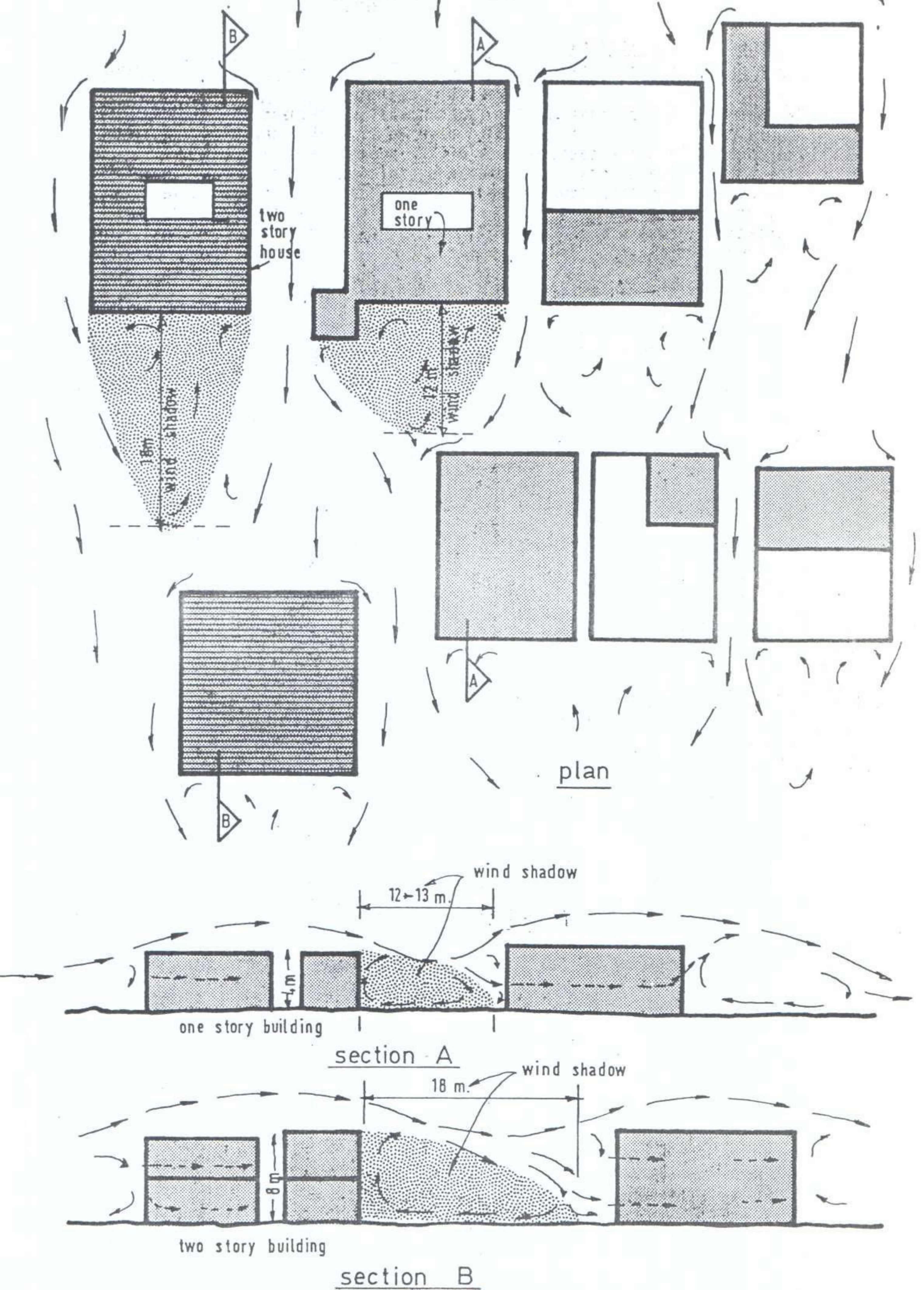
8.2 Settlement Patterns

8.2.1 Physical Influences (Fig. 8.3)

Because of the fact that Salala is a coastal settlement between the mountains and the sea it tended to develop linearly, parallel to the sea. The coconut palm plantations back of the each are a natural dividing „line between the coastal fishermen and exslaves' barasti houses and the substantial limestone town houses inland. Because of the relative scarcity of agricultural land there are few buildings within the date grove plantations and the coastal settlement is effectively separated from the town settlement of Salala proper.

The availability of materials can be seen to respond somewhat to the location of certain groups of buildings'in that the barasti houses are located close to the palm groves and the limestone houses in areas where the, soil is thinner and limestone can be readily quarried.

FIG. 84 Air Flow Around Buildings in Salala Old Town Centre



8.2.2 Climatic Influences

The major climatic factior effecting the situation of buildings in the Salala area is air movement. During the summer the onshore breeze is encouraged into each house. Air movement is the only relief to the constant warmth and extremely high humidity conditions of the summer months. Houses must be situated not only to accept maximum breeze but

so as not to severely block ,air movement to the houses behind. Buildings are generally well spaced and oriented to facilitate maximum air movement, although houses along the beach are found to be built closely side by side, each ensuring an open front to catch the breeze.

Ideally one would choose to have ones house situated so that there were no obstructions between it and the southern exposure so .that air could reach the front of the house with its maximum velocity. It can be noted though that when one places an obstacle in the path of the wind, a wind shadow.or reduction in its velocity occurs; but at some distance to the lee of the-object .maximum velocity will be regained. Of course the dimensions of the obstruction influence the extent of the wind shadow.

This phenomena suggests the reason that the Salala town houses are placed well inland of the planted belt. Settlement tends to be in bands parallel to the coast. In Salala proper this is true. Although there were traditionally no formal roads there are wide open spaces between rough lines of buildings. This spacing allows the southerly breeze enough distance to regain sufficient velocity, after being obstructed by neighbouring houses, to provide the required cooling effect once it has passed into the house.

A predominant feature of many of the traditional Salala town houses is the large yard in the south front of the house which is defined by a low perimeter wall. This open area is the property of the house owner, and serves the function among others, of ensuring that no building can be erected too close to the front of the house to interfere with the breeze reaching the windows of the south wall.

A study of Air Flow around buildings in the central area of the old town of Salala shows this phenomina clearly. (Fig 8.4)

8.2.3 Social-Economic Influences on Settlemint

The indigenous settlements of the Salala region strongly reflect social or economic groupings. The fishermen's barasti and mud plastered barasti houses are·of course located along the beach, where the fisherman can be near his livelihood and keep his tools nearby (his boat, nets and catch). The large barasti settlement of one time slaves is still found nearby the Sultan's seaside palace where their employment was traditionally found.

Local tribes each tend to fit into some particular economic or occupational group and the settlement organization of the town of Salala reflects this. Even though houses in the overall settlement appear to be widely spaced and scattered they are grouped into definite tribal and family areas.

Local sheiks in each .tribal area still tend to .hold a great deal of the power on the municipal level. Such area is located centrally near the palace and between the beach (shipping convenience,customs etc) and the old residential town centre.

With the huge influx of refugees into the Salala area changes have occured in 'the settlement pattern. The growth of the town is limited by the boundaries of the militarily secure area An increase in population density has resulted. Since the indigenous pattern is scattered most of the first new settlers built in open spaces in their own tribal areas in the existing town.

The efficiency of the natural ventilation system described in the previous section is dependant on a certain spacing between buildings. The system breaks down when houses are clustered together. In fact the optimum density was found in the town centre of Salala proper. Any new construction will only interfere with the air movement. Another problem in increasing density of the town is found in the traditional primitive sanitation system. Because. there is bed rock close to the surface of the ground sewage has no chance to flow away or be purified by natural organic action, it quickly saturates the soil and becomes a health problem. This had been a problem even in the widely spaced traditional layout but with an increased density is serious. (Fig. 8.5).

The local municipality is trying to cope with this sewage problem by encouraging the digging of cesspits into the bed rock where liquid sewage is drained. The sewage is periodically collected by the municipalities pump truck to be used in its raw form as agricultural fertilizer. The sewage in its liquid form can be fed directly into the traditional Falaj system. The safety of this system is questionable for health reasons, in that it could possibly pass on parasites through food which might be raised on this raw sewage fertilizer, though apparently it has been tested and found safe.* The municipality does not have the facilities as yet to cope with the present expanding population of Salala and in general services do not exist for a majority of the population.

* Royal Engineers - Salala

Fig. 85 SALALA TOWN CENTRE

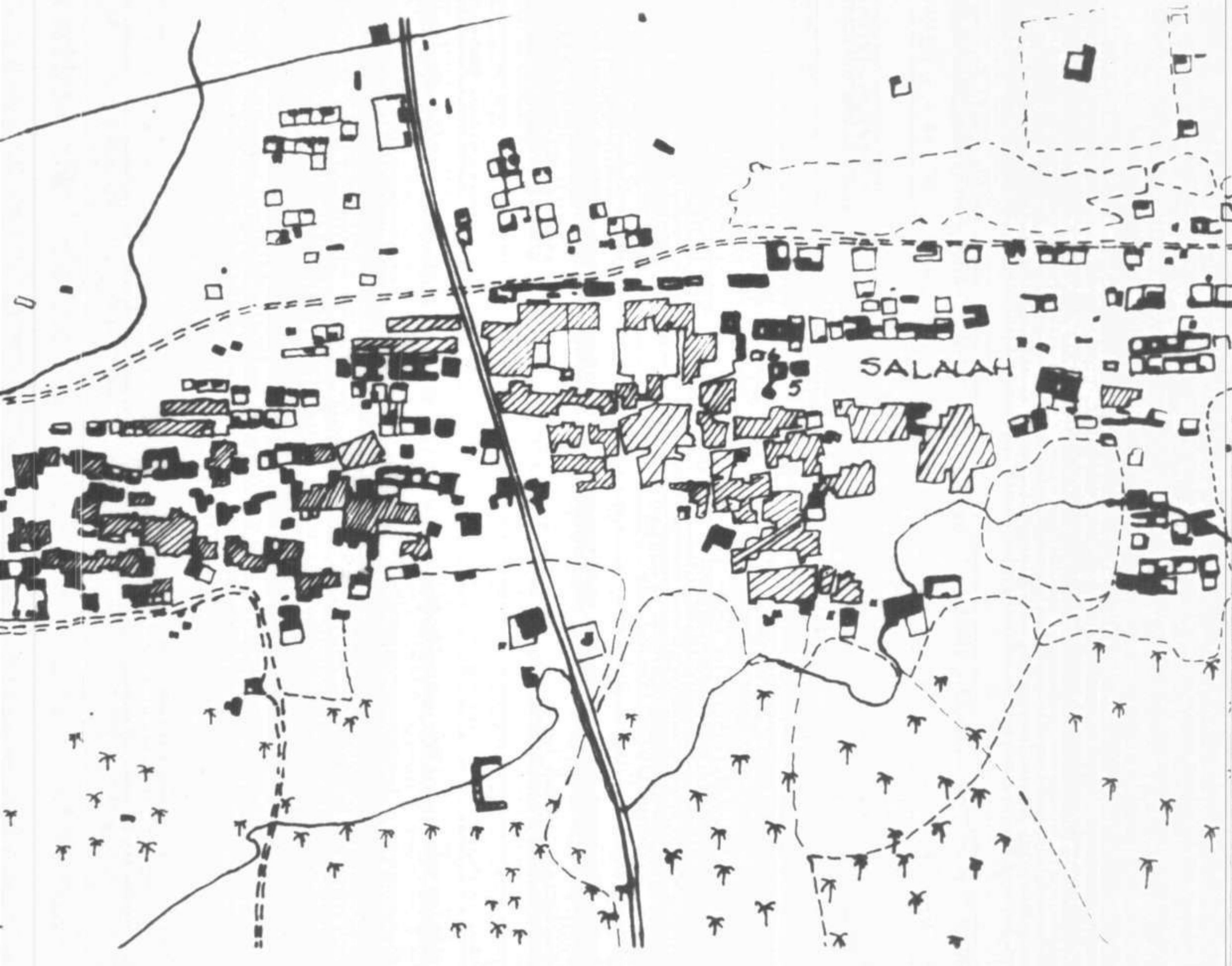


Fig. 86

Refugee settlement of low standard has grown in open areas as a response to immediate housing needs.

Early government solution to refugee problem. Barracks-like dwellings also of poor environmental quality.

New areas for settlement of refugees have been opened up outside the old town, at a density greater than the traditional pattern. Standard 20m x 20m plots are assigned by the government for building. The construction of houses is purely the responsibility. of the owner of the plot. The plots are laid out so that .the houseican be aligned with the prevailing wind if desired and spacing between the lots whenever possiblelillows space for air movement and future services. However, the problems 'of' increased density exist in the new areas as well as` in the old town. Shelters of very low standard (Fig 8.6) have appeared in open spaces throughout both the new and old area.

Added problems occur in the traditional tribal nature of settlement grouping. New settlers want plots adjacent to their old tribal area or areas where members of their tribe have already settled. This situation has created tensions and problems which are extremely complex and likely will only be solved with time.

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ma.

8.3 House Form

8.3.1 Evolution and Social Influences

The basic social Unit was :traditionally and still it. in many cases the extended family. Quite often a-number:of brothers:will occupy the same house with their respective Wives and families after their parents have died. The.extended family unit also tended to exist as a single economic unit, with the elder member directing or in control of the family enterprise (whether it be fishing, trading or herding) as well as being the family head in social matters. Junior members of the family were not given responsibilities to carry in these matters. The family house was of course inherited by the heir to the family power. The house therefore can be seen to represent the accumulated wealth of many generations. As the family grew more rooms could be added to accomodate it. In this way the growth of the house need not reflect an actual growth in the wealth or prosperity of the family from generation. to generation; as each generation need only extend the house as much as the previous generation, to see a continual growth of the house.

Originally a family gaining a plot of land, would build on it as to their financial resources at that time, choosing suitable materials, and methods of construction, but always bearing in mind future growth and change.

A family with little wealth would firstly establish a perimeter wall and a temporary shelter within. This may be built in barasti as a short term measure but if he has the possibility of advancing his economic position he will likely soon begin to build with a more permanent material such as limestone. He would always have in mind to eventually build on more than one floor, or at least to provide the base for his children to do so when the need arose. Limestone is therefore an excellent building material. Load bearing walls can be built to take several stories, and limestone can be re-used in future changes to the house.

In recent years the traditional economic systems of Salala have been destroyed or changed due to a number of reasons, including the war. Little employment is offered in the traditional crafts, or trades and young people have looked outside, to the Gulf region for employment. The social structure of the family .has changed correspondingly with a shift of economic power away from the elders to the younger members. The young sons now with money of their own have much more independence and has resulted in many more houses being constructed for young families, or families of brothers working in a co-operative way. This phenomlna in combination with the influx of refugees has resulted in a great increase in the rate of building. Building on the other hand has taken forms very similar to the traditional evolutionary house growth. A family always builds bearing in mind future expansion. This may be the reason for the continued use of limestone over other material's such as concrete, even though the price is greatly increasing. Its reusability is advantagious when considering growth and adaptability and its massiveness forms a base for the addition of more floors.

Because of the increase in building activity it is possible at this point in time, by surveying various houses of families in differing stages of building, changing and extending, to clearly see the evolution of the house form particular to the Salala.region.

The basic form is the court yard house. Once the perimeter wall surrounding the house plot is established rooms begin to be built around a central court yard. Plots tend to be square. This is always true in the new government assigned areas. The basic plan is almost always symetrical, with the entrance on the southern wall in the centre or slightly off centre. The first roomto be built is either at the front (south) of the plot with windows facing the open space in front of the house, or at the back of the site opening on to the court yard. One of the factors considered here is the encouragement of air movement into the rooms.

As stated earlier if the house builder is poor he may begin to build in barasti. Gradually with time he will upgrade his house by possibly using mud plaster, (Fig87b) or extending his house or replacing parts with more substantial materials such as limestone or concrete. (Fig87c) Many houses make use of a conglomeration of materials indicating various stages of the evolution of the house.

The growth of the house in time takes place in almost a spiral manner. Once the ground floor is completed using load bearing materials, rooms are constructed at the front (south) on the first floor. Construction continues to the back around the court yard, then construction next begins at the front on the second floor. (FigB7e)

In many cases the houses are completely owner built, this is particularly true for those using indigenous materials, but in some cases the house owner will contract out certain parts of the construction, such as roofing or concrete walls. Often he hires labour to help in the work, but since the extended family and tribal ties are still strong, labour can be organized in a co-operative way for these building projects.

Evolution of the Courtyard Town House
Fig. 87

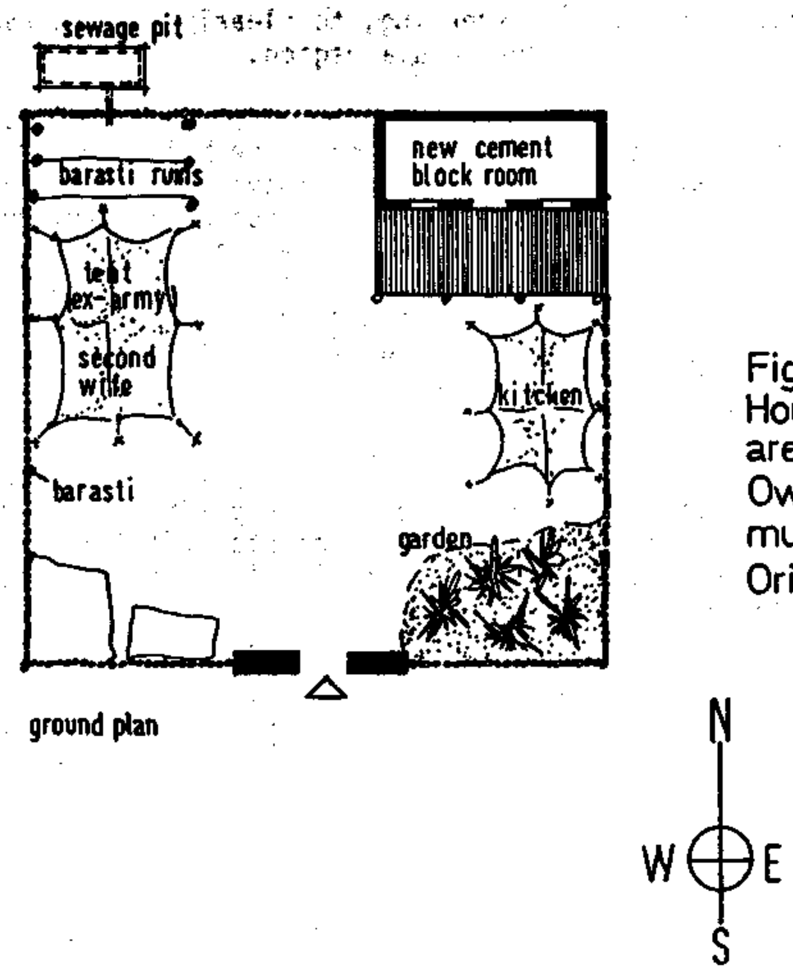


Fig. 87a
House in new settlement area, land from gov't. Owner employed by municipality as Askary. Originally barasti

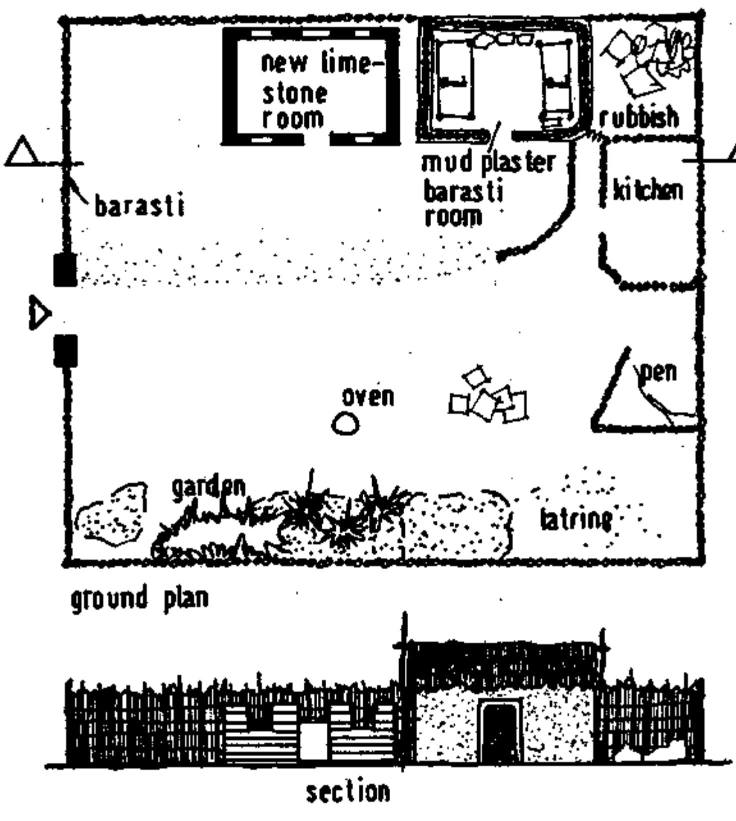


Fig. 87b
Mud plaster and barasti house with limestone addition in new settlement area.

Fig. 87c

One story house in new settlement area. Extended family ownership by three brothers. Construction basicly limestone, with barasti and composite roofing. Extensions underway.

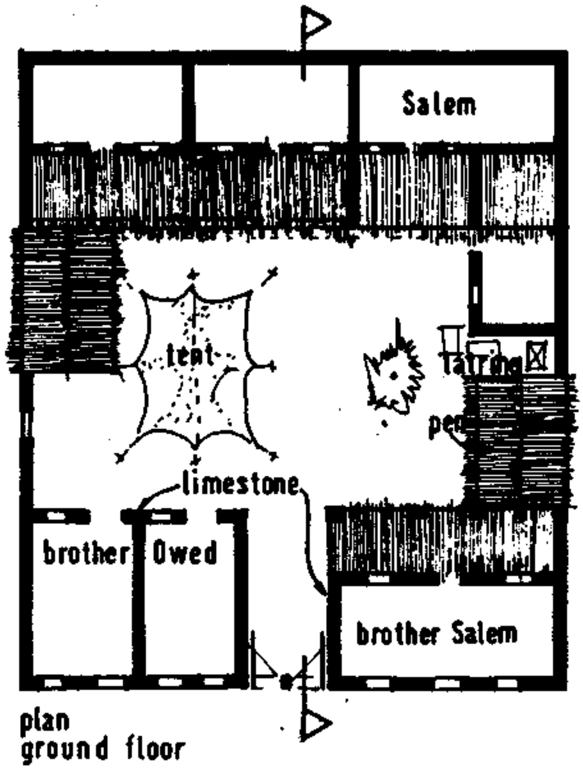


Fig. 87d

Two story house in old town centre of Taqah. Limestone construction with vaulted barasti roofing.

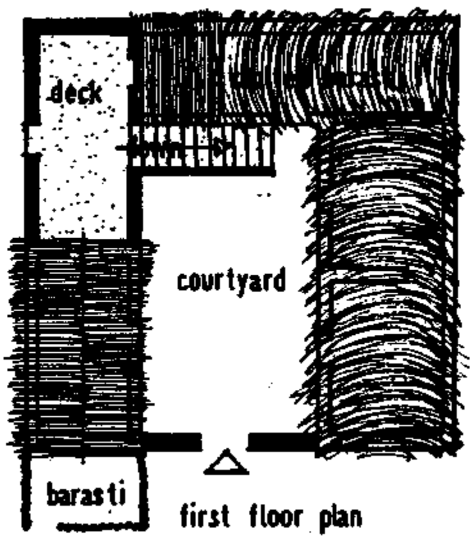
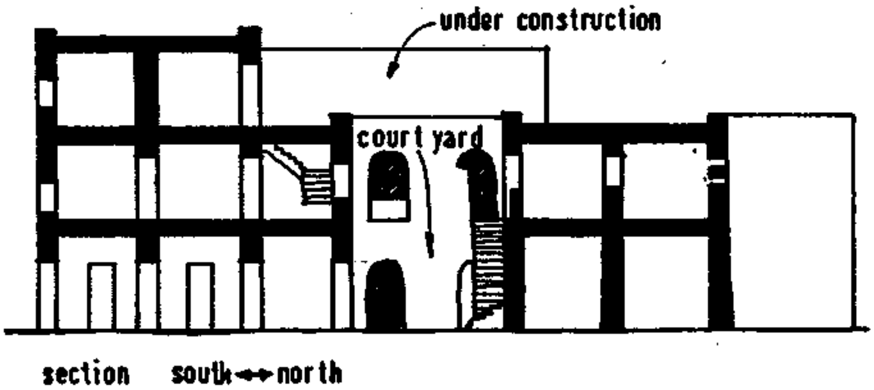
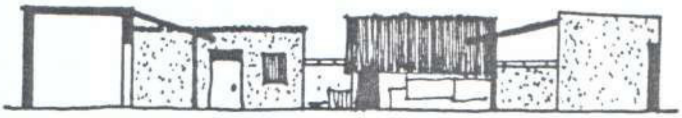


Fig. 87e

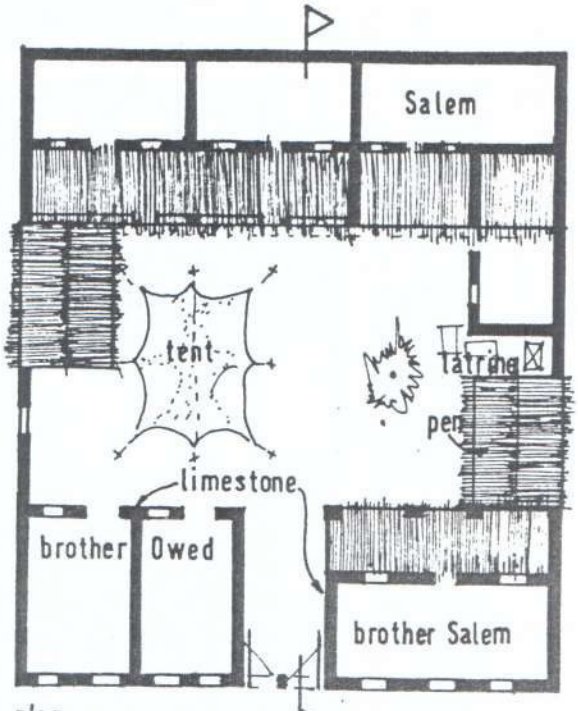
Three story limestone house in old town centre of Salala.
60 to 80 years old. Extensions underway.





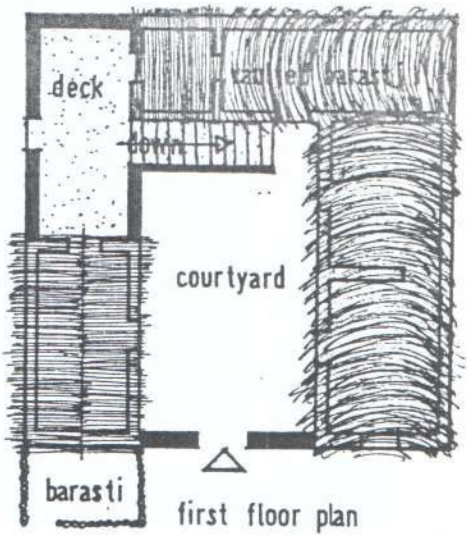
section

Fig. 87c
One story house in new settlement area. Extended family ownership by three brothers. Construction basicly limestone, with barasti and composite roofing. Extensions underway.



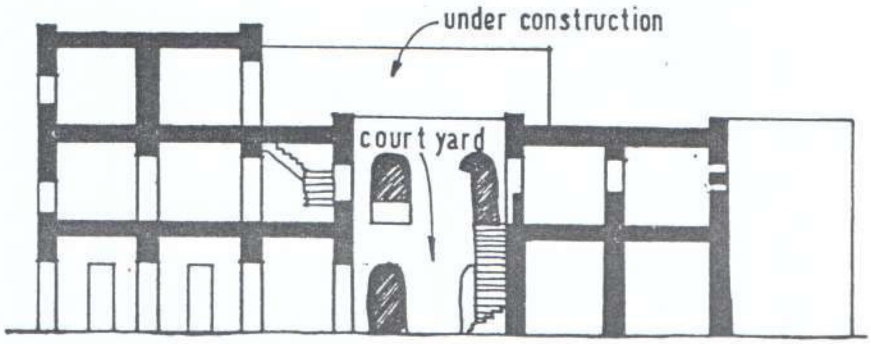
plan
ground floor

Fig. 87 d
Two story house in old town centre of Taqah. Limestone construction with vaulted barasti roofing.



first floor plan

Fig. 87e
Three story limestone house in old town centre of Salala.
60 to 80 years old. Extensions underway.



section south↔north

8.3.2 Climatic Response in Building

There are predominantly two types of building in the Salala area. Firstly coconut palm frond stem (barasti) structures.. found close to the seaside - and secondly substantial limestone houses found predominantly in land or in old established built-up areas.

The situation of these twolorms of construction is largely social and economic. The barasti houses on the coast being occupied by the descendents of slaves of the Sultan are near the palace. Sardine fishermen along the shore also live in barasti houses. Barasti of course is a far less expensive material to use than limestone. It also can be seen to respond directly to the local micro-climate. The atmosphere in the area directly adjacent to• the beach has a relatively higher humidity to that further inland. As a result air movement should be encouraged to induce a certain amount of cooling. Barasti walls generally allow air movement as they are porous. Open lattice walls and openings to allow cross ventilation are 'predominant design features in this area.

As one moves back from the beach it is noted that barasti is used in combination with a clay plaster to produce more substantial' buildings. The rendered walls stop air movement so that windows are now incorporated into these houses. The clay barasti walls have thermal.insulative properties which are advantageous in the cool winter nights and stand up much better.to the abrasive actions of the severe winter winds.

Limestone construction has been used as the pripcipal material for houses of the townspeople and merchants. The traditional town houses of Salala take on fortress like appearances and the use of heavy limestone construction is a response to somewhat hostile social and physical conditions.

A study was carried out on building materials used in the Salala area in order to understand their response to thermal conditions which change from season to season. Qualities of each building material particularly their heat transfer properties (defined in Climatic Introduction Section 2), have an effect on modifying internal micro-climates of buildings. Each material transfers the heat, built up on the outside faces of a building exposed to the sun, into the interior of a building with a different rate and with varying efficiency.

The materials chosen for testing were limestone, barasti panels plastered with mud on both sides and concrete block. Rooms were selected from houses in the new settlement area of Salala which were built in each of the three materials. Each room tested had the same orientation and was free standing. Limestone walls are approximately 50 - 60 an thick while mud plastered barasti walls are 8 to 10 cm thick and concrete block walls 15 to 18 an thick.

Tests were carried out in October 1973 using protable testing apparatus. The external and internal wall surface temperatures and corresponding external and internal air temperatures are recorded for the three materials on graphs 810 a to c.

The thick limestone walls transfer heat quite slowly having a high thermal capacity. Sunlight (solar radiation) causes exposed exterior wall surfaces to heat up. It generally takes about 18 hours for a portion of this heat to reach the interior of the room (Fig 810a). This means that some of the noon time heat from the outside is transferred slowly through the wall and is radiated into the interior at about 6 o'clock the next morning which is the coldest time of day. This is advantageous whenever the night time temperatures fall below comfort levels. This happens in the winter months in Salalat On the other hand in the late spring and summer months, during the season of high humidity there is very little direct sunlight as the conditions are generally misty or cloudy. The fact that interior surfaces do not heat up due to solar radiation and there is a very small daily temperature range results in the limestone walls heat transfer action being negligible. In this season air movement must be encouraged to maintain comfort conditions.

Mud plastered barasti walls and concrete block walls transfer heat much more quickly into the interior than do the thick limestone walls and more of the heat built up on the exterior surface actually reaches the interior.

The time that it takes for heat to be transferred by conduction through the mud plastered barasti wall is 5 hours (Fig 810b); Approximately 60 percent of the external heat reaches the interior.

The heat transferred through a concrete block wall takes 3i hours to be conducted from the external to the internal wall surface. 75 percent of the external heat passes through to the internal wall surface.

In comparing the performance of the three materials it can be seen by looking at internal air temperatures that in each case comfort limits are exceeded for most parts of the day. Air temperatures within a limestone room are consistantly one or two degrees above the upper limits of the comfort zone. Within a mud plastered barasti walled toam the temperatures will be comfortable in the morning and at night but will be above the comfort limit in the afternoon and hottest in the evening. Air temperatures within a concrete block room will be well above comfort limits by late morning and continue through the afternoon and evening.

Fig. 810a

Limestone block room

Salala

October 30,1973

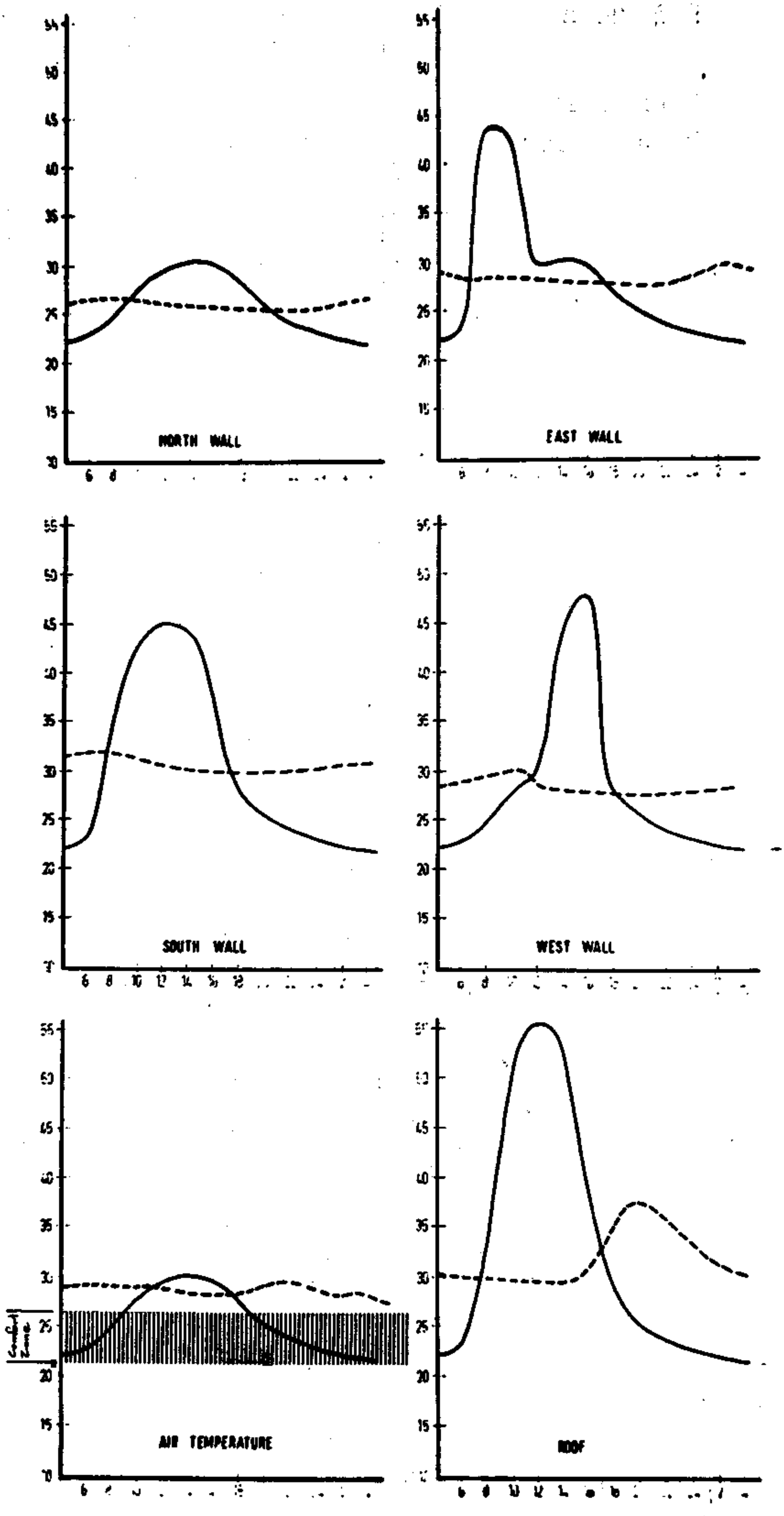


Fig. 810 b

Mud plastered barasti room

Salala

October 26, 1973

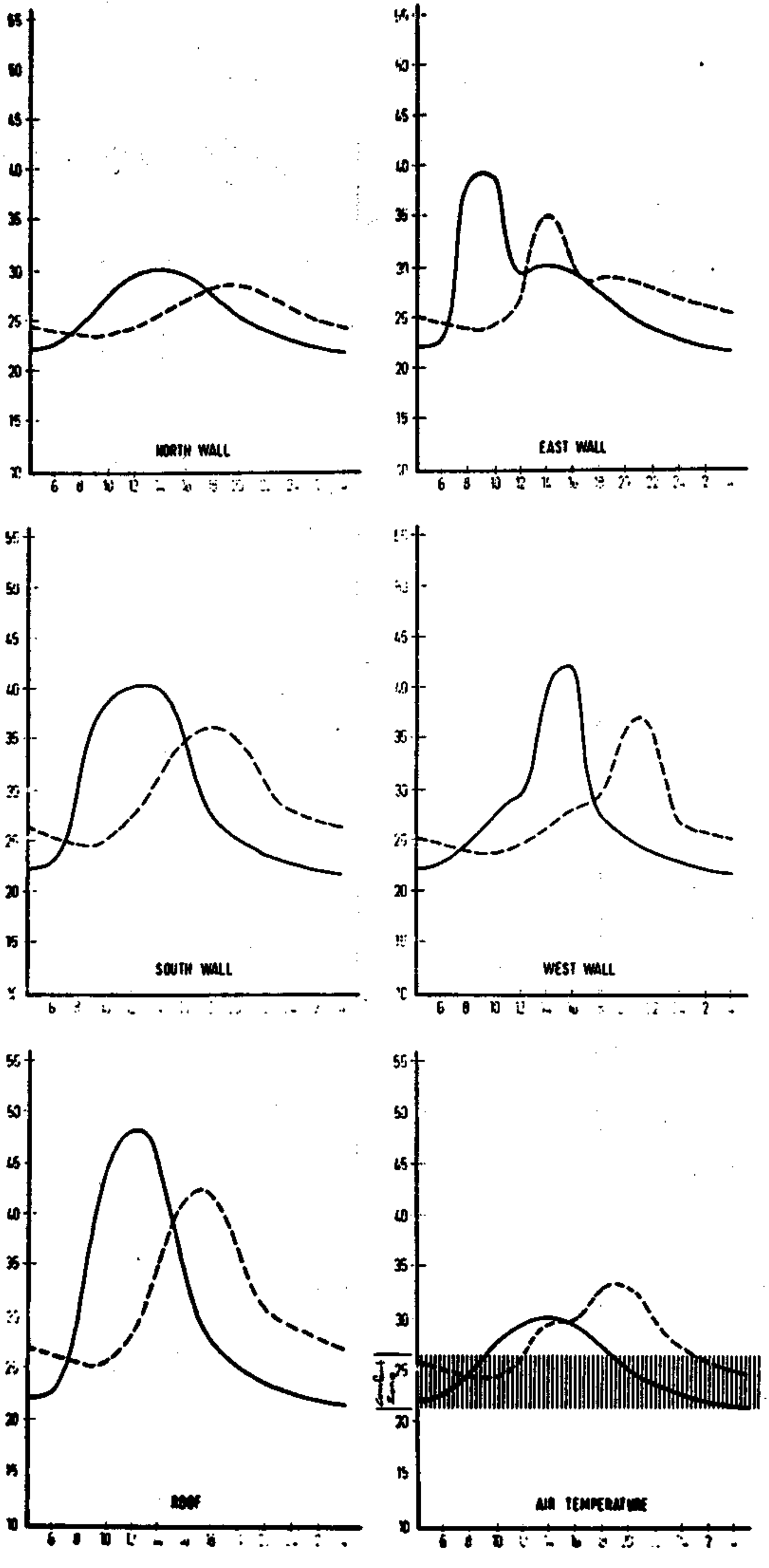
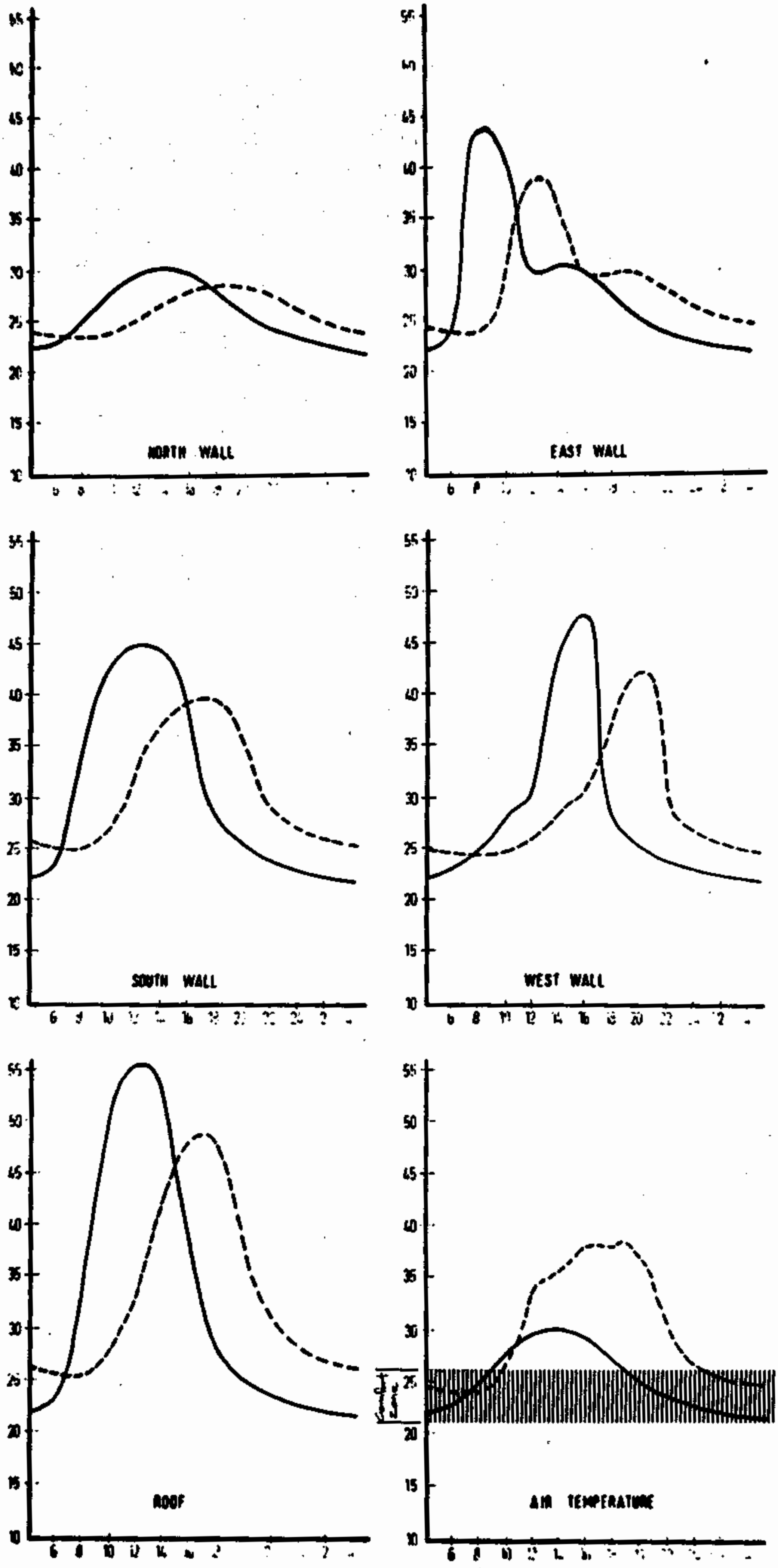


Fig. 810 c

Concrete block room

Salala

October 24, 1973



To discover how the three materials limestone, mud plastered barasti and con= crete will respond to the Salala climate during the coldest month of January graphs can be drawn (Fig 810d to f) using information extrapolated from the three previous graphs and the climatic charts (Fig 81 and Fig 82).

In Fig 810d it can be seen that the temperatures within the limestone block room are consistantly found to be comfortable even though the temperatures outside fall below comfort limits during the morning, evening and night.

Temperatures within a mud plastered barasti walled room (Fig 810e) fall into the comfort zone in the afternoon and evening but are below comfort limits in the morning.

Within a concrete block room (Fig 810f) temperatures are found to be comfortable at noon and in the evening but too hot in the afternoon and too cold at night and in the morning.

It can be concluded that the heat transfer properties of limestone are advantageous in maintaining moderate comfortable temperature conditions within a building, particularly in the cooler winter months. During other times of the year the heat transfer properties of each material tested are incapable of producing a comfortable thermal environment inside buildings. Therefore other factors such as air movement must be considered in the design of buildings in the Salala region.

Fig. 810 d

Limestone block room

Salala

January
coldest month

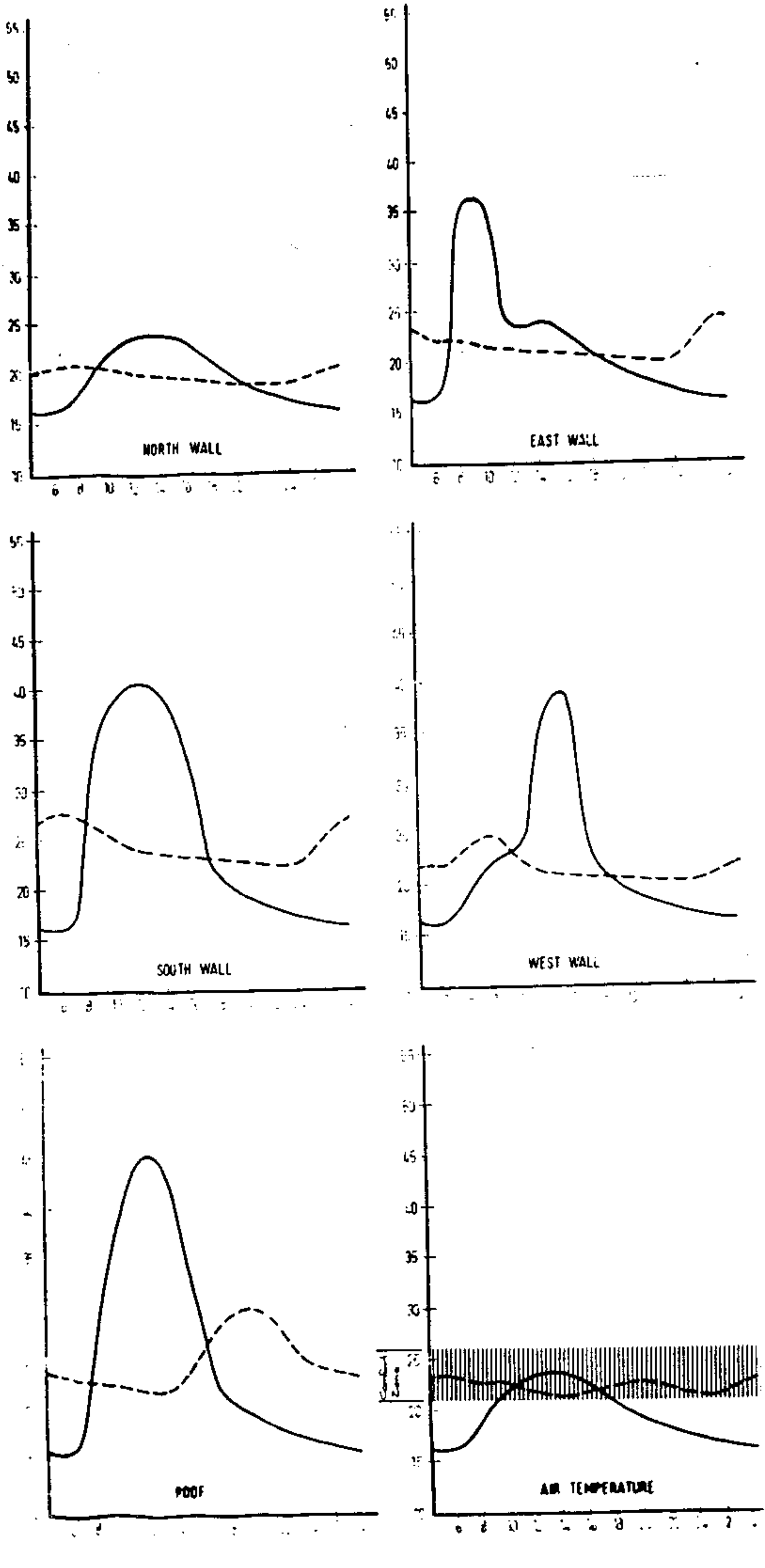


Fig. 810 e

Mud plastered barasti room

Salala

January coldest month

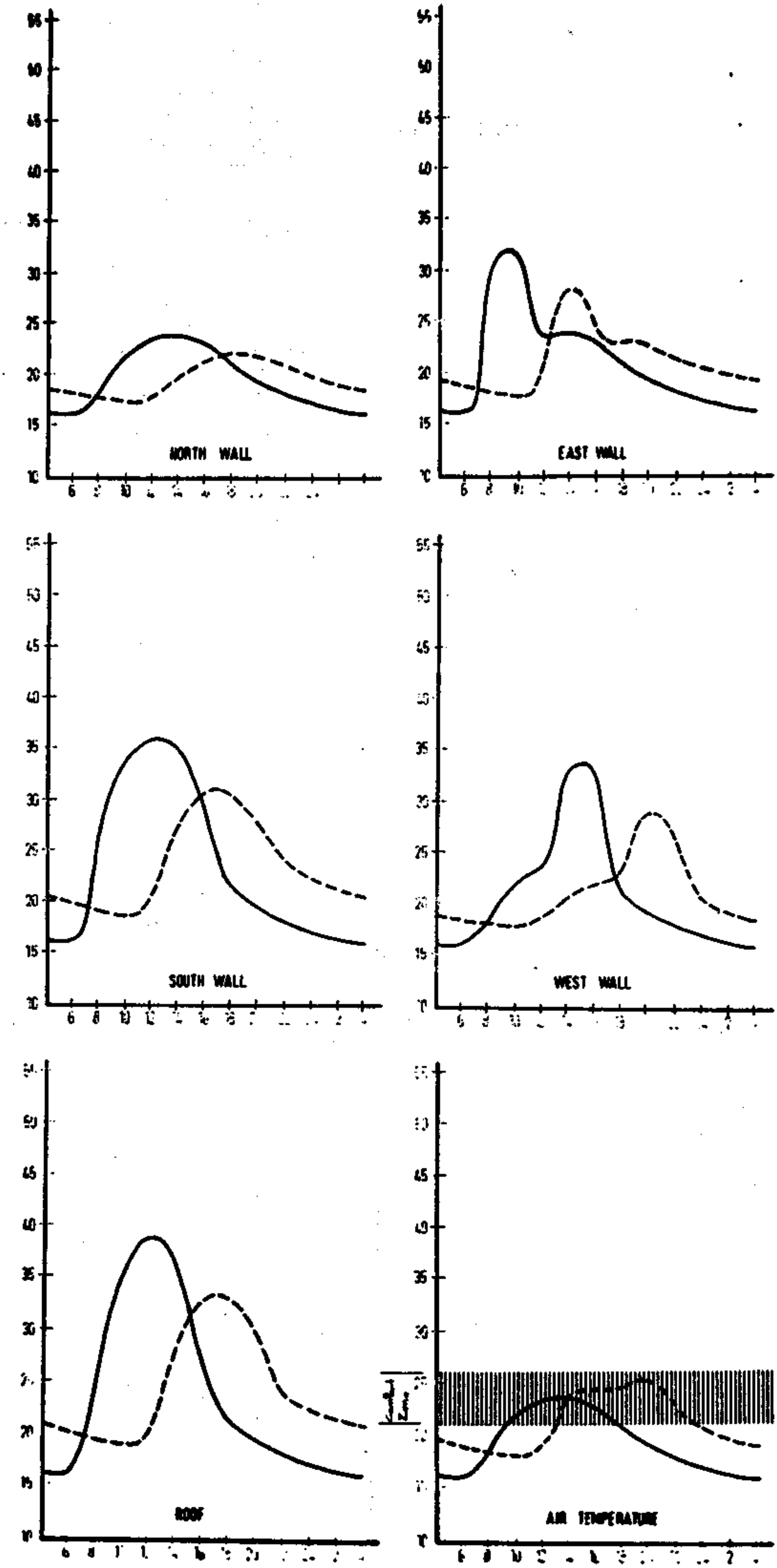
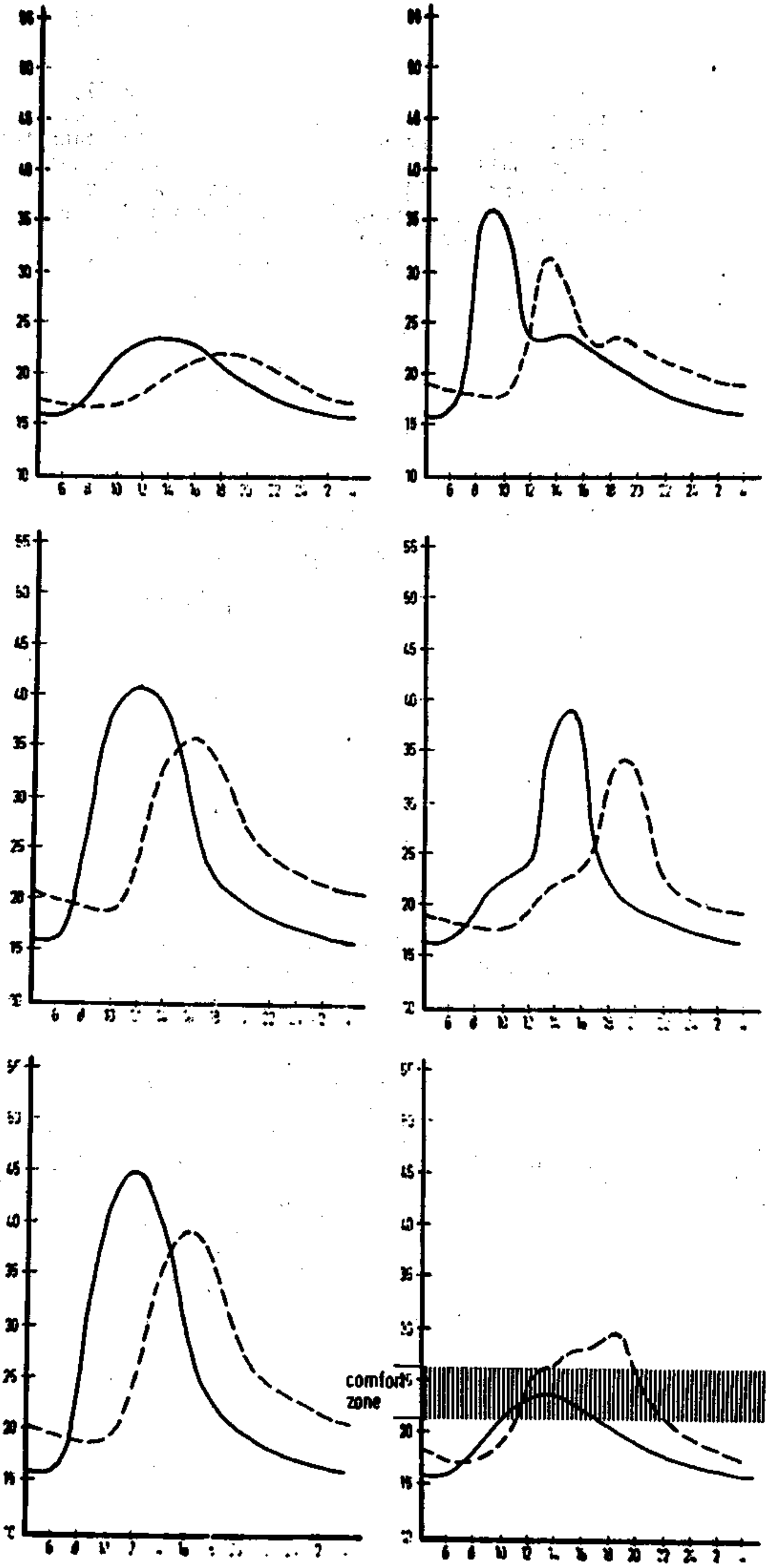


Fig. 810 f

Concrete block room

Salala

January coldest month



The traditional town house of Salala (Fig 813), incorporates a large open front yard facing the south (toward the sea). Climatically this ensures that this space will remain open to allow air to reach the front of the house. The south wall of-the house itself is pierced with numerous large openings (above ground level) to allow air to pass freely. The predominant house

form being the courtyard house reflects this need to encourage air movement. This form allows the house to be set up so that at any point it is only one room deep and cross ventilation can always occur.

While the south wall is open to accept the summer breeze the north wall has few openings and they tend to be small. This blank north wall is against the cold, dusty northerly winter wind mentioned previously.

A study was carried out in order to determine the response of the traditional courtyard house Salala's climate (Fig 814).

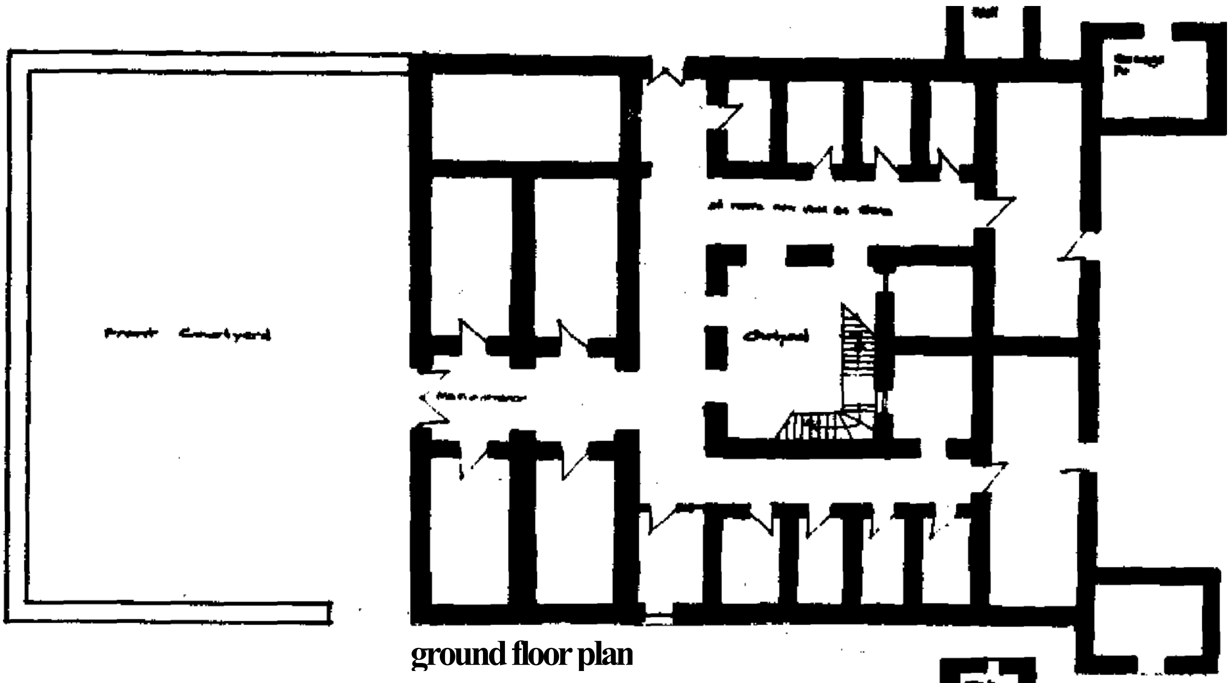
At night (seelillustration for 24.00hr) there is little air movement due to the diminishing effect of the land/sea breeze condition as the land and water temperatures are similar. The principal of radiant heat (or the transfer of heat energy through space from a warm body to a cool one) becomes important. The relarively warm earth radiates heat energy to the dark sky (particularly on clear nights). Exposed horizontal surfaces i.e. flat roofs rapidly cool thus cooling the adjacent air. This cool dense air on the roof, finds the lowest available spot and settles into the courtyard, displacing any warm lighter air which may have remained there. The courtyard becomes a cool air ‘well’.

As the night progresses to early morning (refer'to illustration for 5.00hr) the land continues to cool and falls significantly below the temperature of the sea. A land breeze results. The north wall with small openings receives little air movement. Cool heavy air continues to be deposited in the courtyard well.

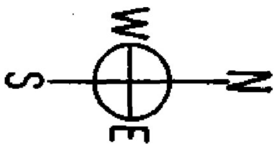
With the morning sunlight (drawing for 9.00hr) land begins to heat up again approaching sea temperature. Air movement tends to disappear at this time. Roofs and south walls are heated up because they receive direct sunshine. The courtyard remains shaded and itspool of cool air is protected. As the temperature of the house rises,cool air from the courtyard flows into the rooms off the court, encouraged by the relatively low pressure area outside where the hot light air rises from the warm surfaces.

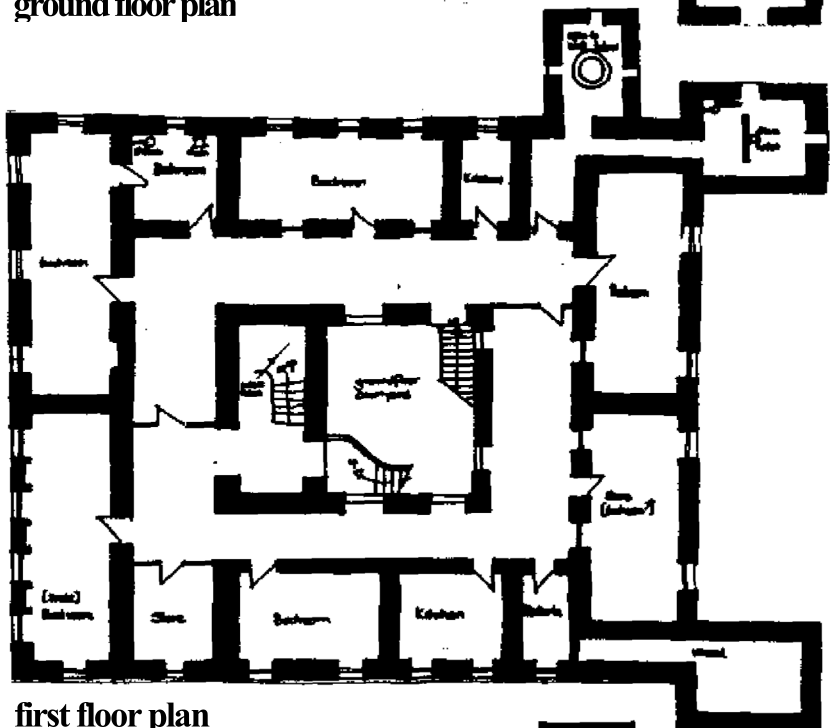
As the day progresses and the land warms (refer to drawing for 14.00hr) and the sea breeze takes over. Air movement passes freely through the rooms of the house. Due to the friction of the eartht surface velocities are greatest on the second floor level and diminish towards ground level. Air movement should be encouraged to aid in evaporative cooling on the skin's surface. Wall and roof surfaces heat up due to the sun's radiation but most of the courtyard remains in shade and stays cooler, still trapping the denser cool air.

* Reference: The Courtyard House as a Temperature Regulator. Daniel Dunham New Scientist Sept 8 1960.

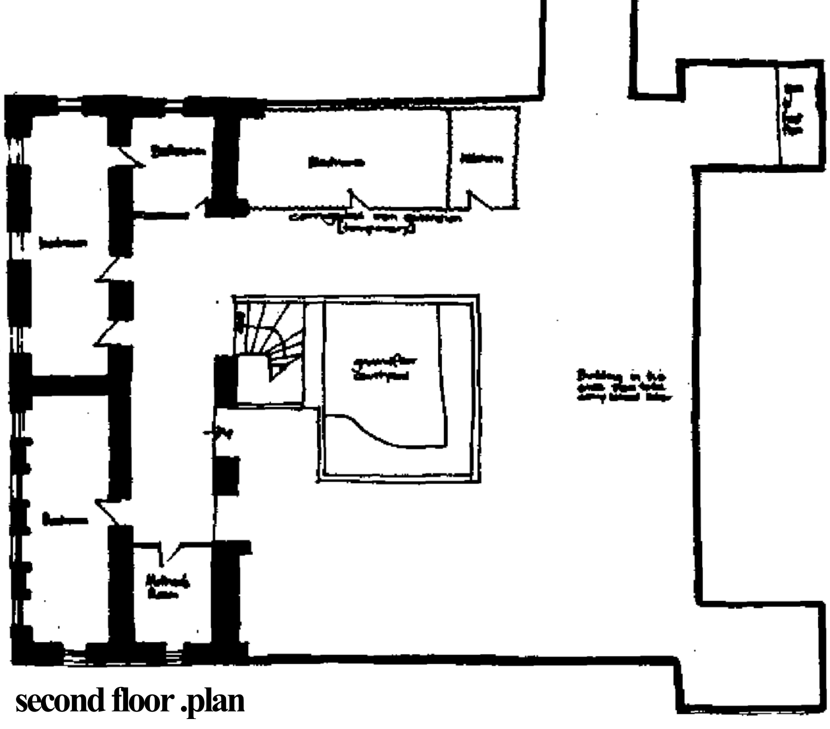


ground floor plan





first floor plan



second floor .plan

Fig. 813
Court yard house in Satala old town centre.
60-80 years old.
Limestone construction.
Extensions still underway.
Inhabited by extended- family of several brothers.

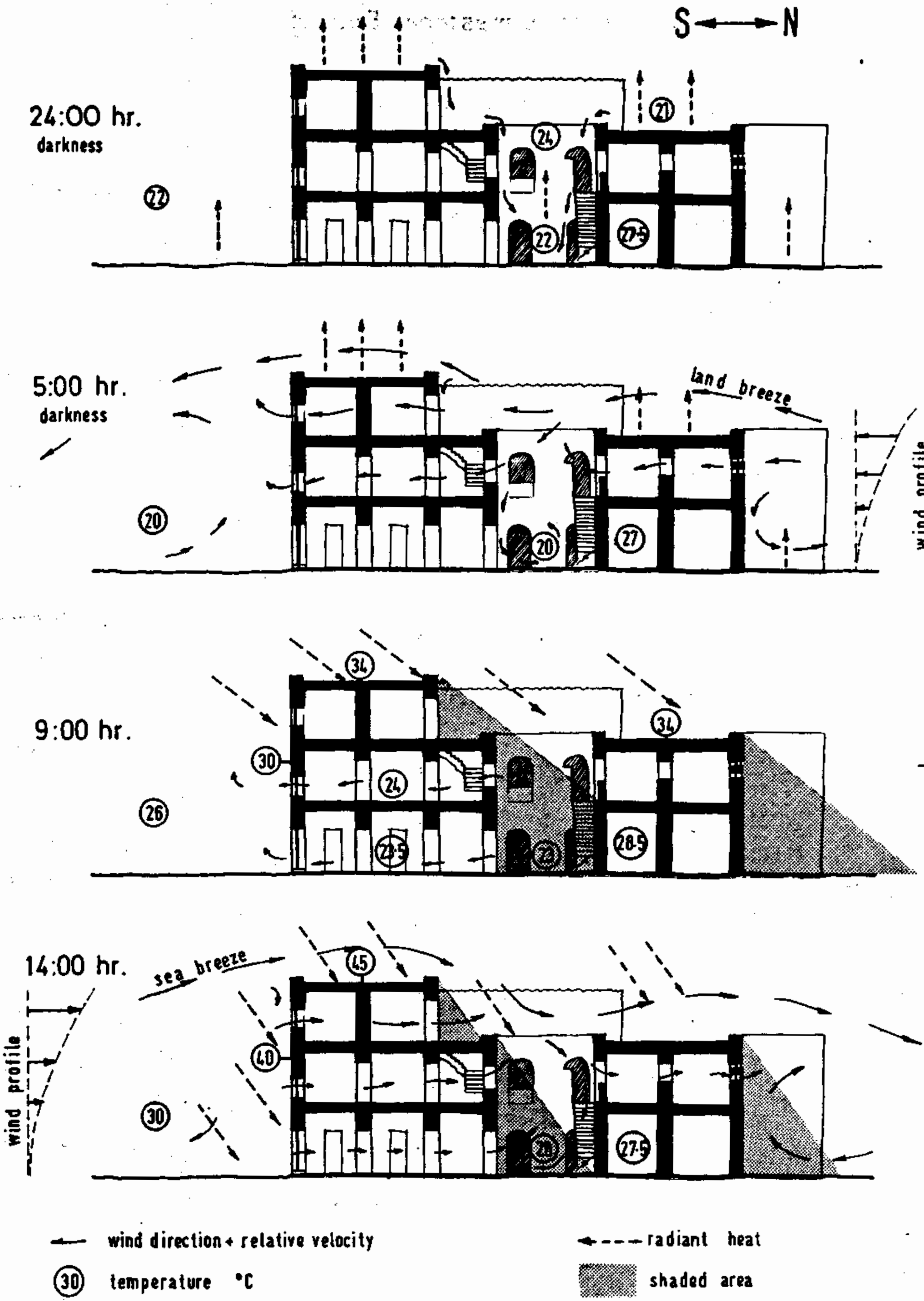


Fig. 814
Climatic Response of Salala Court yard House · Oct. 28,'73

Problems Due to Limestone Bedrock

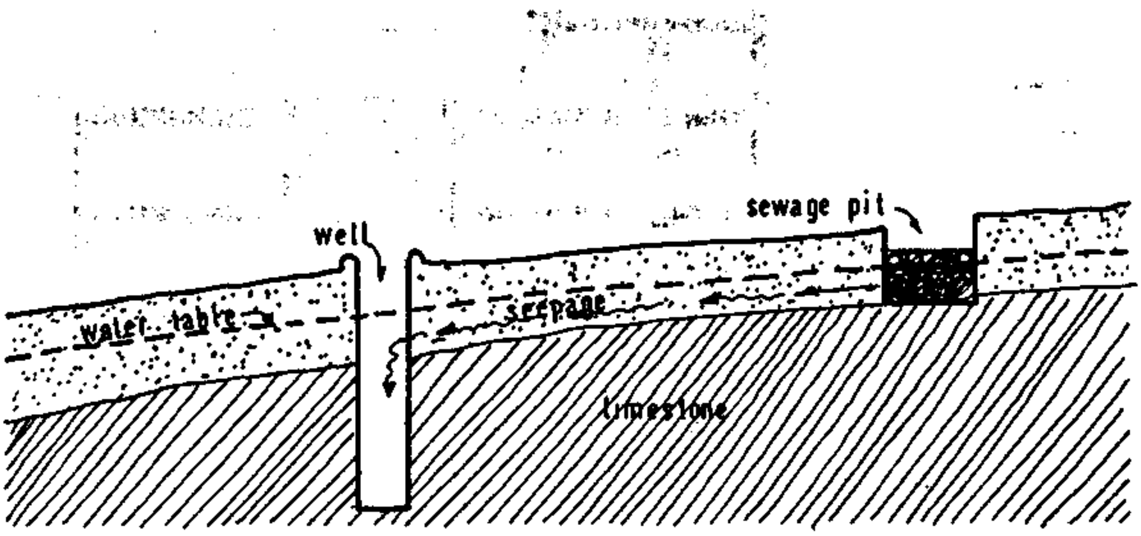


Fig. 814
Sewage pit seepage into wells

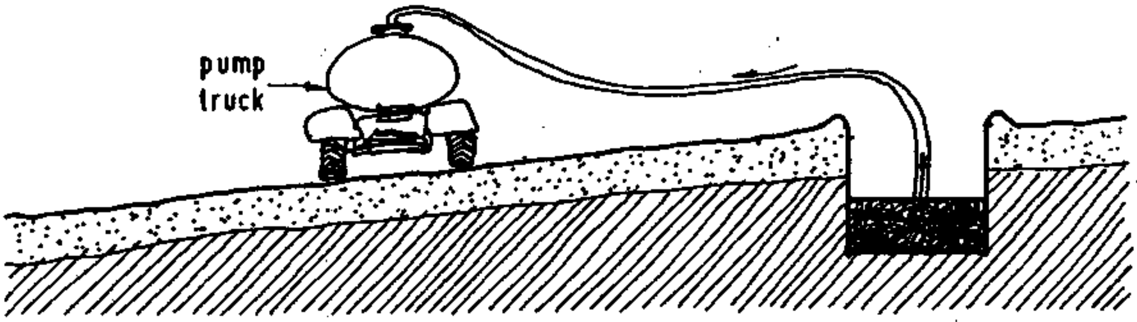


Fig. 815
Pump truck drainage of pits

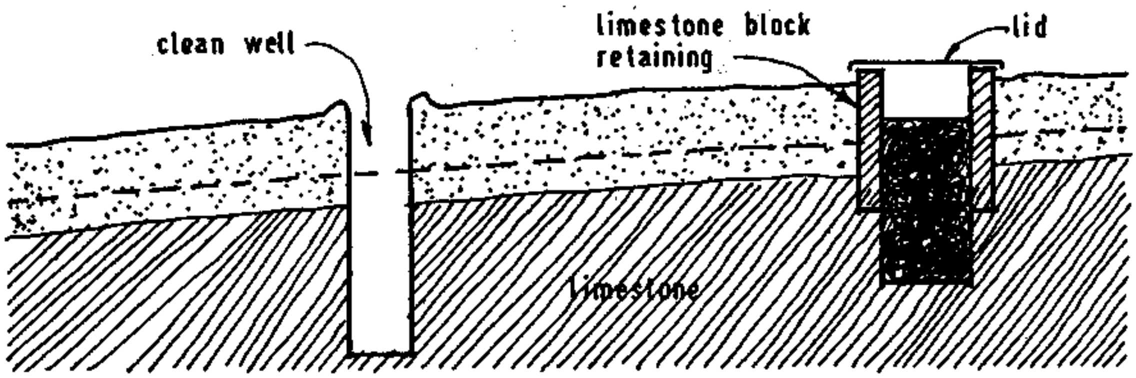


Fig. 816
Pit retained with limestone block preventing seepage

8.3.3 Materials

8.3.3.1 Limestone

The narrow coastal plain around Salala consists of a thin layer of soil, the limestone bed rock being at most only about one meter below the surface. Although this limestone provides abundant building material the shallow soil condition creates many problems. In some areas thin soils restrict root development of agricultural planting such as palm groves.

Drainage and sewage disposal are particular problems. Where the water table is particularly high i.e. in the settled area along the shore, this problem is even more critical. Sewage disposed of in shallow pits (Fig,814) quickly saturates the thin soil layer and will not drain through the limestone layer. Sewage can quickly pollute nearby wells.

To help alleviate this problem pump trucks are used in conjunction with sewage retaining pits (F19815) which are quarried out of the limestone, and sewage is spread for fertilizer on fields. This system can be employed where the water table is low enough i.e. below the bed rock level but in most residential areas the water sits on the bed rock and would normally flood these pits. In these cases concrete or limestone block work is needed to retain and waterproof these pits above bed rock level. (Fig 816).

Limestone is formed by the compression over time of marine deposits such as coral. The hardness of limestone therefore depends on its relative age, the older being the hardest and best for building but the most difficult to quarry. There are in Salala buildings several centuries old made of hard limestone still in excellent condition. Goad hard limestone from old buildings is used again and again in successive generations of building. Unlike most other building materials such as brick, wood and concrete limestone is almost a completely recyclable material.

In general on the Salala coastal strip (formed by either the gradual uplifting of the land or the recession of the sea), the limestone further inland (near the mountains), is harder than that near the shore that is still actually under water. Because of the political-military situation making access to areas near the base of the hills difficult, limestone is now quarried nearer the shore. This results in a softer grade of limestone being used.

This poorer limestone generally weathers faster and is damaged easier so when it is reused it is usually in a broken and more irregular form. This results in recent changes in limestone building systems and details using smaller pieces (to be discussed later).

Quarrying Systems:

Limestone being found close to the surface is generally quarried from shallow open pits, though there are a number 'of methods of extraction.

The majority of new limestone blocks used in construction in Salala are hand cut from open pits. The limestone cutters first chose a site nearby an area of building where the stones will be clear. If the limestone is not already exposed on the surface, the thin layer of soil above the bed rock will be excavated.

Each cutter stakes off an area to work in himself and begins cutting. With heavy iron pike, wedges and a hammer he first digs grooves or deep cuts down vertically to the desired dimensions of the block (by plunging with his pike). (Fig818) Then with wedges he breaks off the block horizontally at the base. (Fig8l9) The rough block is then trimmed and stacked.

Stone cutting is extremely heavy work and is carried on in most cases by the local negro population. Each man works for himself and can cut about 20 blocks per day. Some men can apparently cut many more. The stone cutter sells his blocks at 25 to 30 Rials per 100. The price is said to be about 32 Rials delivered. The best structural limestone is quarried in this way.

Limestone is also quarried by hand in shallow water in pits near the shore (water table being very close to the surface). As mentioned earlier the limestone along the shore has been formed much more recently and is softer and less resistant to weathering but it is much easier to quarry. The cutter feels with this pike for seams in the stone where he cuts in a similar manner to the previous method. When a large piece is loosened, being quite light it can be easily brought out of the pit where it is cut and trimmed into blocks. The stone from these underwater pits fetches a somewhat lower price on the market.

The third method of cutting limestone is mechanicil. The local government has been experimenting with a limestone cutting machine in order to reduce the cost of blocks in their own buildings. Non structural facing blocks were ,being cut at 30cm X 25cm X 10cm to cover concrete block work. In

theory a relatively small crew operating a machine can turn out more precise blocks per man than can those using the traditional system. The manufacturer of the machine being used * claims that the machine when used on a good site by a foreman and a crew of 8 or 9 can produce 700 blocks per day. (Fig.

In practice this total has never been reached. The system often only produced 100 blocks, or much less, per day. The limestone in the quarry area was coarse, with small pebbles in suspension. Apparently these pebbles tended

to dull the blades very quickly. Blades must be constantly sharpened and one should always be kept in reserve. The foreman also suggested that a spare axle be kept in reserve because this was another weak spot in the machine.

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*FAS/TR ERALDO CAROFOL TERNI (RIVO) VOLABOLOBRECCIAOLO (150-151)

Fig. 818
Deep cuts are made by driving pikes down into the limestone bedrock

Fig. 819
Blocks are broken off

Fig. 820
Limestone cutting machine on track

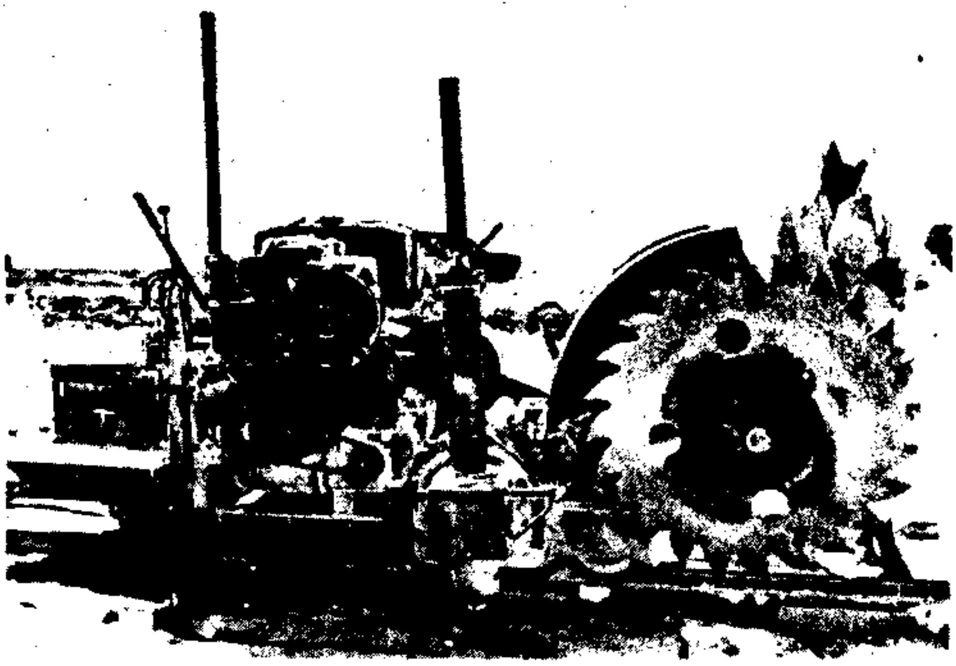


Fig. 821
The machine cuts parallel lines, then lines perpendicular to these

Fig. 822
Block is cut horizontally using the traditional method

Fig. 823
The track must be moved manually after every cutting run of the machine

The process of cutting is as follows: (mechanical)

1) Clear top soil away from flat bedrock limestone slab.
2) Chalk out lines to be cut en the surface of the slab.
3) Since the machine (Fig820) is set up with a large circular saw blade and runs along'tracks, the tracks must be set up parallel to the chalk lines so that the blade can cut along the chalk line. The blade is set to cut to the depth desired as the dimension of the block.
4) The machine is activated and the whirling blade is brought down to the desired depth, cutting the stone. The machine then advances along the track cutting a continuous deep line. (at the rate of 15m/4min or 4 4m/min. Fig821).
5) To cut the adjacent parallel line the track must be manually pulled over (Fig823) and lined up again.
6) The right angled cuts require that the tracks be dismantled and lined up again.
7) Horizontal cuts which free the blocks must be done in the manual way previously discussed. (Fig822)

As stated above, the site which we studied had a very low output. In fact 75 percent of the blocks cut were waste, substandard or broken. It was clear that the site was not ideal. It is suggested that the size of the site was uneconomical. In this site the machine had only a 15 meter cutting run. With more track laid and a larger quarry site the machine could have a much longer cutting run resulting in fewer track movements.

The machine cutting system as we observed it did not seem to be very efficient. In fact those cutting blocks by hand were more productive per man than those using the machine. The running costs of the machine, its original cost, and the cost of repairs added to its apparent low productivity tend to indicate that it is uneconomical. These criticisms apply to the particular machine or even the blade which is obviously not suitable for the Salala conditions. The idea of improving on the way limestone is quarried is a good one. Some way must be found to reduce the price of limestone which only 3 years ago was sold at 3 R/100. The price has increased by 8 or 9 .times.

Obviously in the manual system of quarrying where a man is working for himself there is a higher incentive to produce than for a worker operating a cutting machine for a contracting company. Possibly the government could invest in the mechanization of the quarrying system on a co-operative base, where those normally working as individuals in the same quarry could collectively operate a cutting machine, thus upgrading the existing system.

It is clear though that before plans for the mechanization of limestone cutting takes place in Salala, improvements are necessary in the cutting machine and the way it is being used. Conscious experimentation must be made with machinery and possibly different types can be used.

Machined blocks are much more regular than hand cut blocks. Their smooth surfaces are used for facing in government projects. If machined blocks become widely used as structural material as well new systems of construction and detailing will have to be employed by the local builder who now use rough hewn blocks.

It is interesting to note that in the past old quarry pits were not left open and unused after the cutting had been completed. It was mentioned earlier that because of the high bedrock'level agriculture and in particular palm groves had difficulty in developing lnrsome areas because the roots of the plant material had little room to develop. A farmer would often invite quarry men, looking for a site to work, to dig on his land. In return for the use of the site, the farmer would receive 10 percent of the quarried stone. After the excavation reached a suitable depth the quarry men would move on and the farmer could infill the site and plant on top. Planting thus had the necessary deep soil for root development and often access to the water table. (Fig824) It is suggested that quarry sites can be used in similar ways in the future.

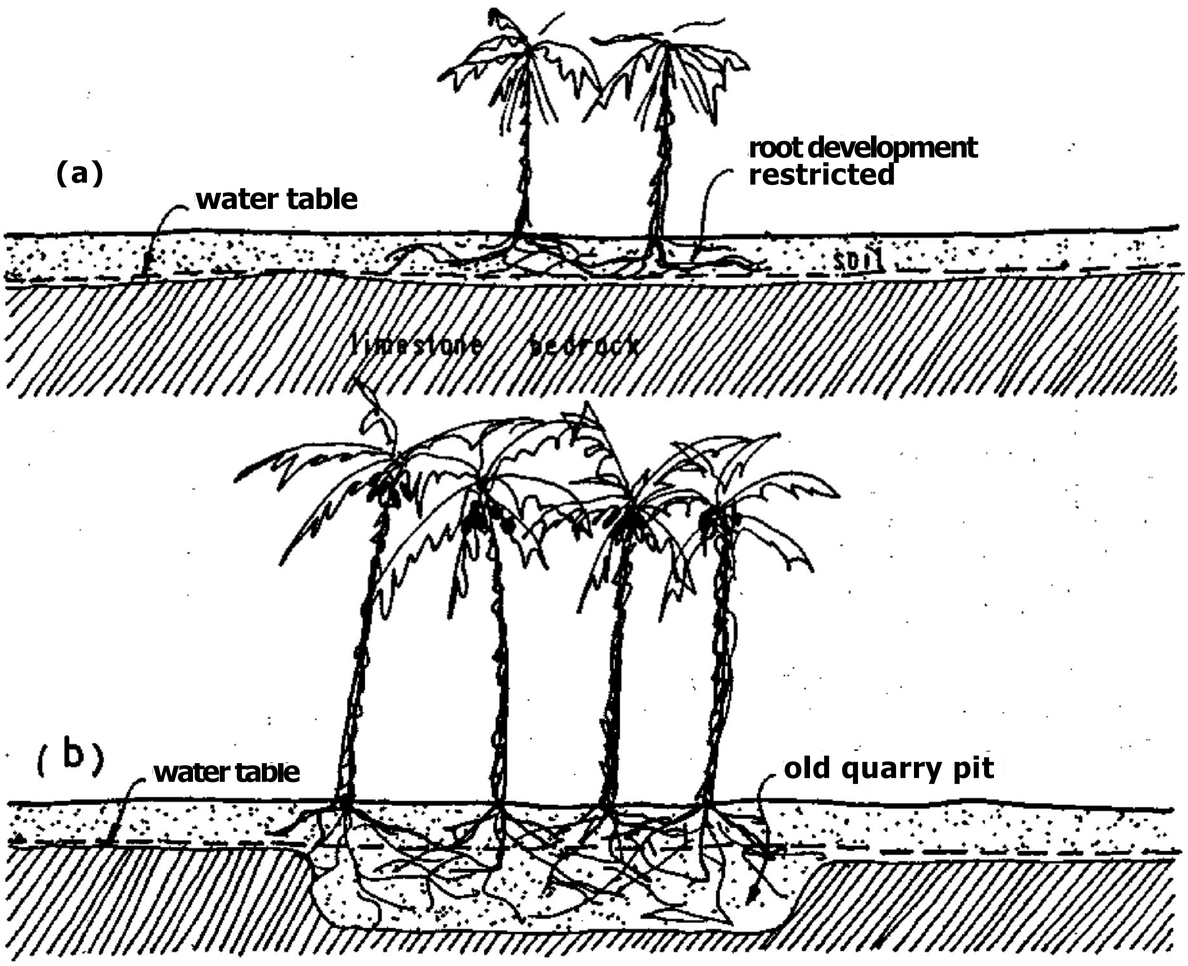


Fig. 824

Improved Planting on Old Quarry Sites

Limestone Construction Techniques:

It has been mentioned that systems used in limestone construction have changed in recent years. This is due to the military-political situation making access to high quality limestone and wood (from the mountains) difficult, and the fact that with the sudden influx of people into Salala whoselivelihoods have been cut off in the mountains, the demand for building materials has been very great.

A) The first system described (Fig825) is the traditional one and is dependant on the availability of hardwood from the mountains. This system applies to the building of houses with more than one story. Shallow footings, if any, are required because of the high bedrock level. The footing to 40-50cm above ground level is made of cut and trimmed limestone blocks.

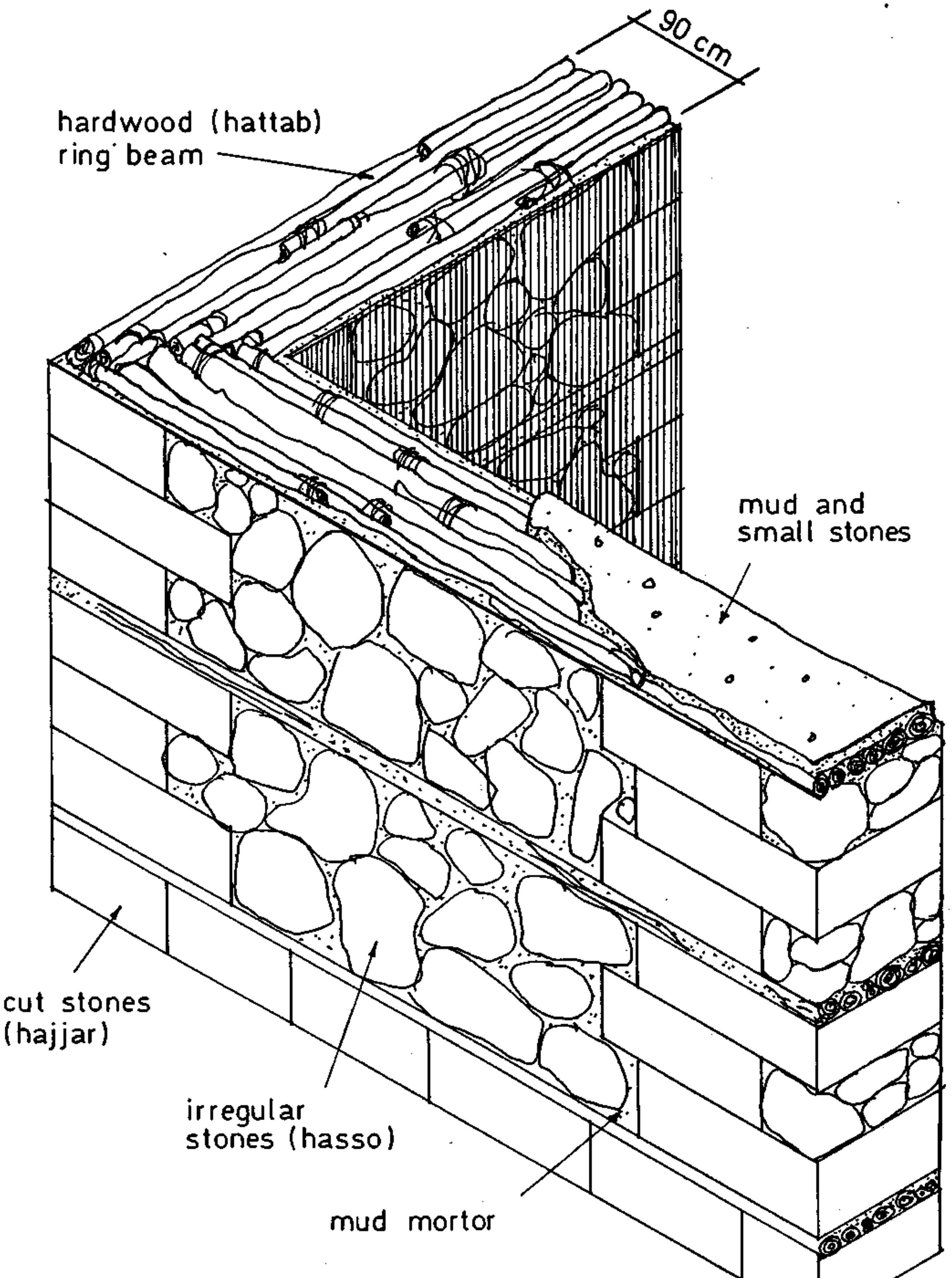
The wall thickness is about 90cm or one and three quarters to two arms. (traditional measurement system. dhira . 45cm) Hardwood (hattab) and branches from the mountains are bound together in a horizontal layer as a ring beam, continuous around the wall. A layer of small stones and mud is used on top of this for levelling, and a base for further building.

Large cut stones (hajjar) are used on the corners and periodically if the wall is long to provide vertical alignment. The volume between the cut stones (hajjar) is built up with smaller, less regular stones (hasso). All stone is set with mud-clay (tine) mortar. Approximately every meter another layer of wood horizontal reinforcing and levelling is set in. This system is no longer used because wood from the olive trees in the hills for the ring beams has not been available for the last several years.

B) The limestone construction system used now (Fig826) does not require wood lateral reinforcing. A system (hajjar sawan) or 'locking stones' was evolved. The demand for stone, its resulting high cost, and the more efficient structural system, have resulted in wall thicknesses being reduced from 1.00 or 0.90 meters to 0.60 meters (or from 2 dhira to 1.3 dhira).

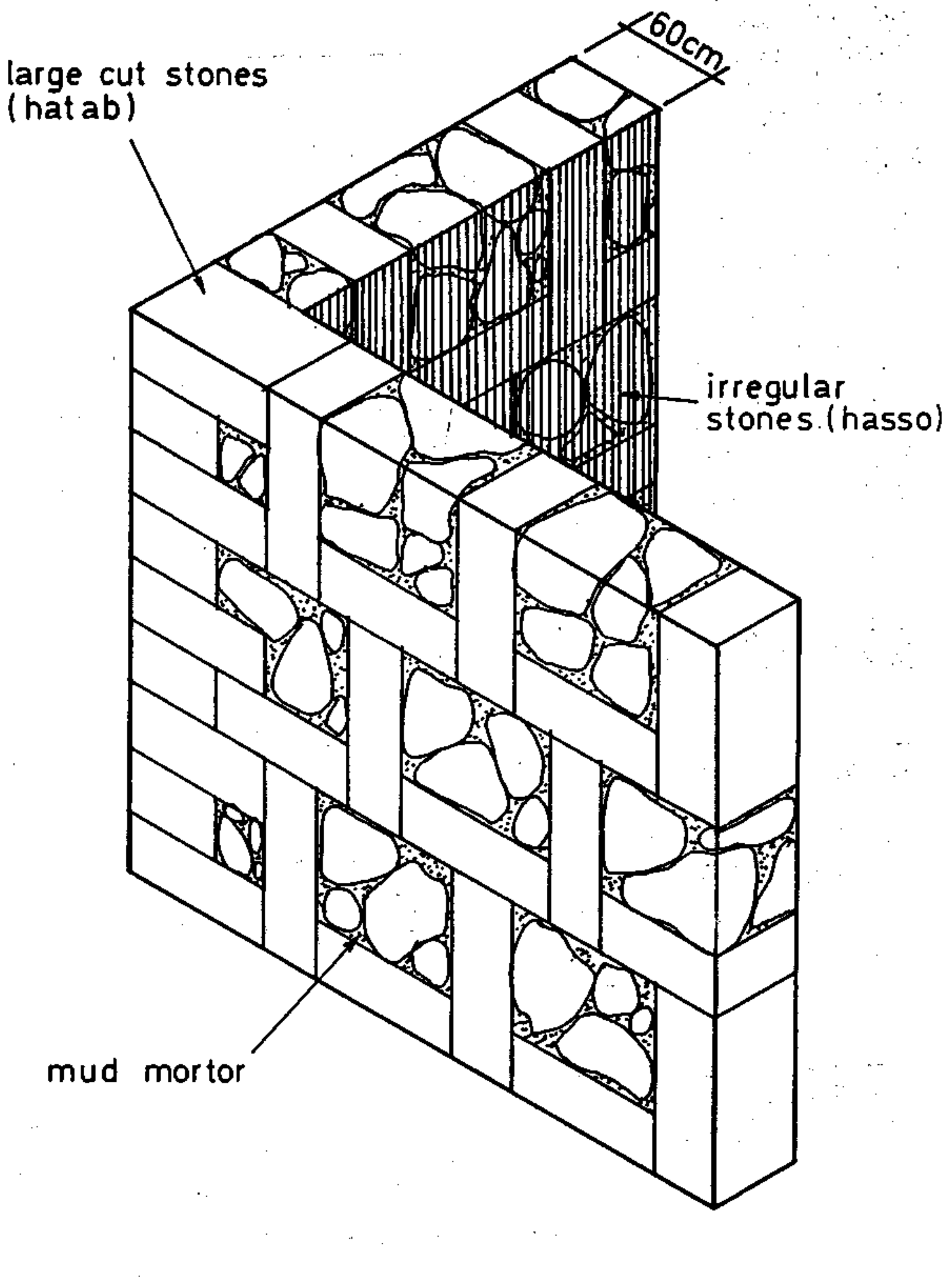
Large blocks (hatab) are set in an interlocking way. Smaller stones (hasso) quarry rubble, or broken blocks recycled from previous buildings are used as an infill between the locking stones. Again a mud-clay (tine) mortar is used for setting the stones.

In comparing the two systems described above it is apparent that the second uses far less stone. On the other hand the newer system seems to require a higher proportion of cut trimmed block. The structural efficiency of each system requires further study. Observations indicate that many two and three story buildings built in the old system have been standing at least 200 years. Multi-story buildings using the new system are not apparent but this is probably due to the fact that a family house grows with time and a second floor is not usually added until a later date. The basic structure caters to this requirement.



Traditional Wall Construction

Fig. 825

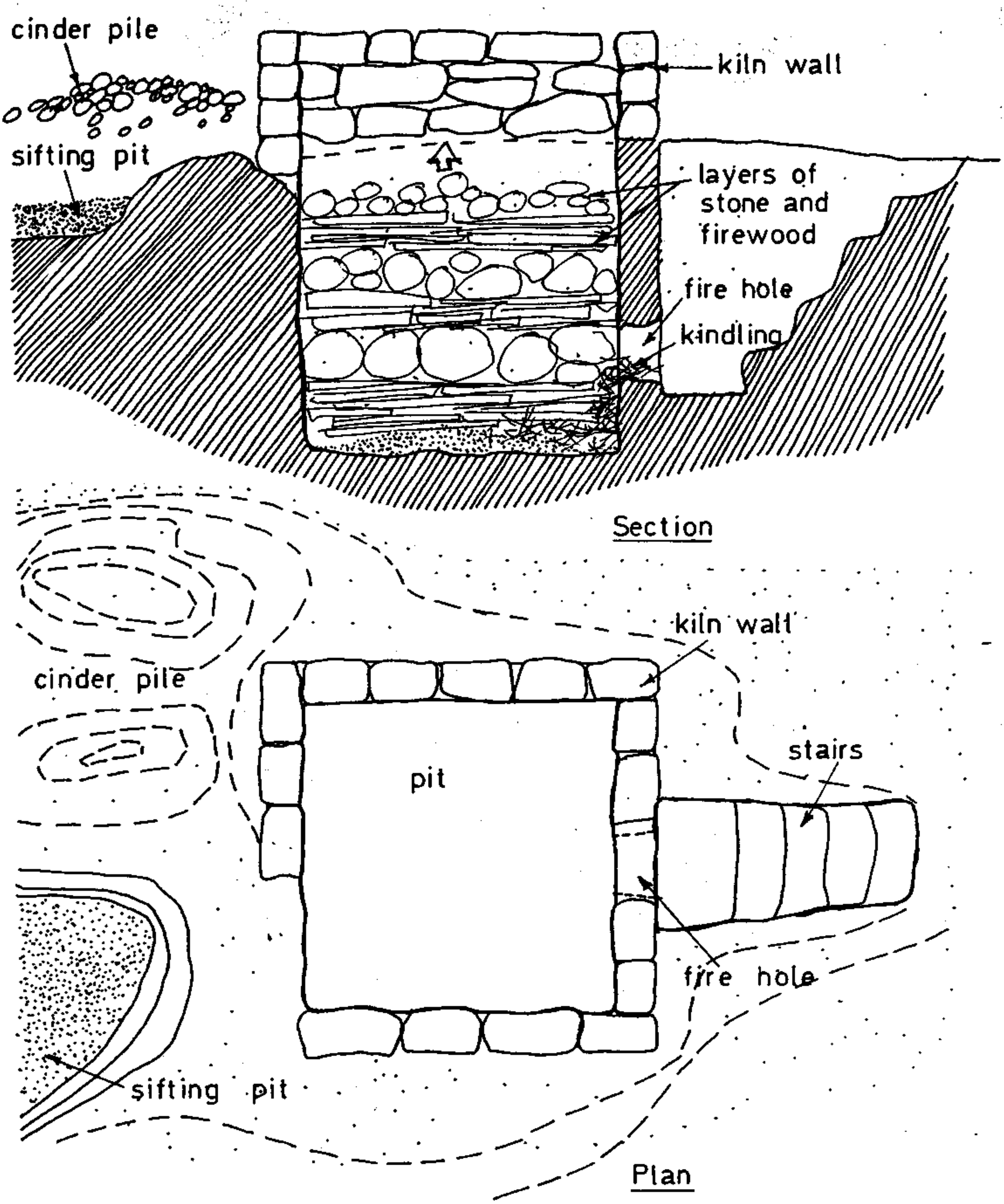


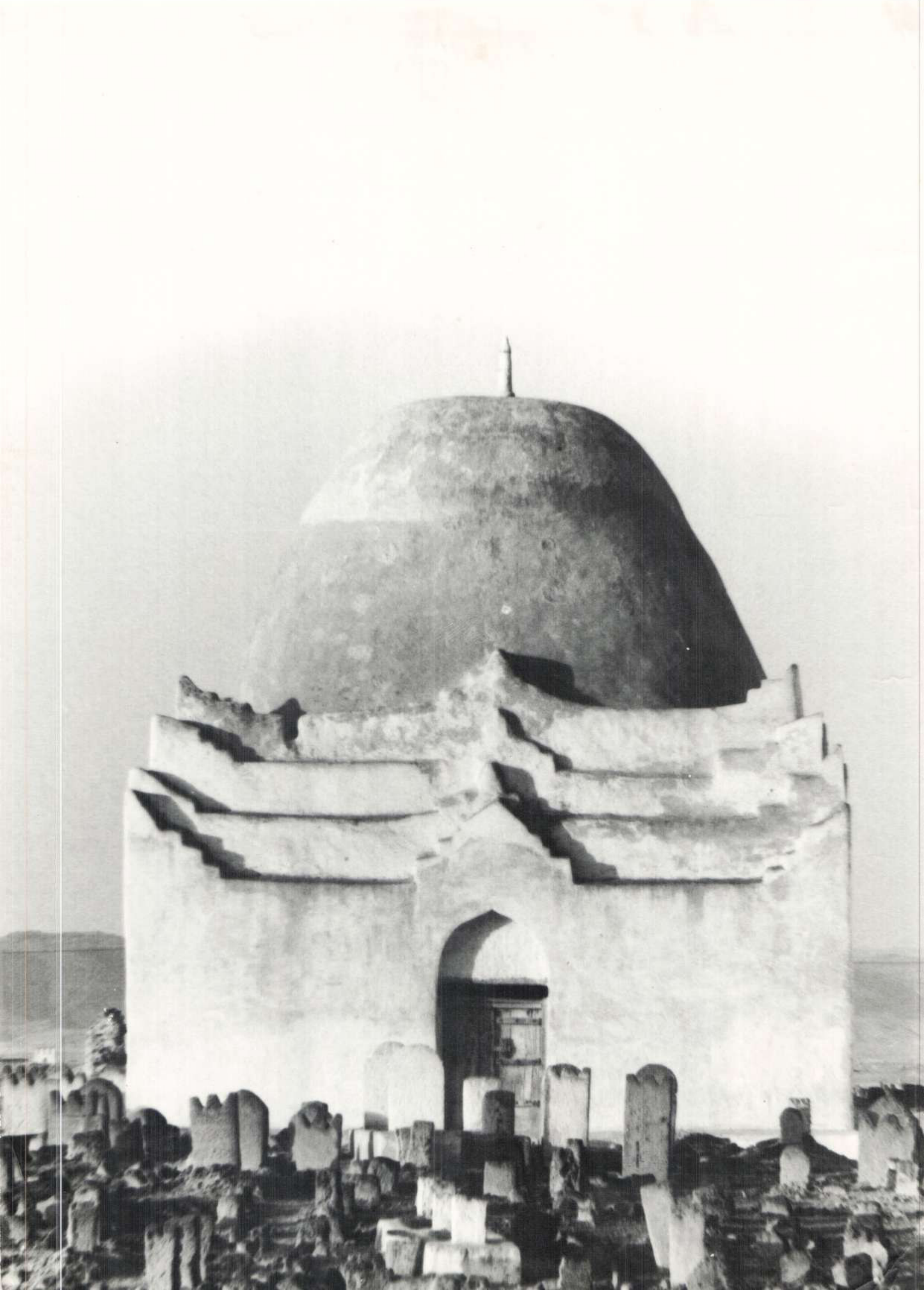
Recent Wall Construction
'Locking Stones' (hajjar sawan)

Fig. 826

Fig. 828

Nourah - Lime Burning Kiln - Pit





8.3.3.2 Plaster

Nourah or Gypsum Rendering

Nourah is used as a rendering material on the exterior and interior walls of many important indigenous buildings in Salala. The Mosques (Fig827) are notable examples, the nourah providing a hard weather resistant whitish earth coloured coating. The mosques being some of the oldest buildings in Salala have been extremely well protected by this rendering material.

The nourah has been produced locally and was fired in kilns, the remnants of which one finds in the Salala area. The location of these kilns depends on the proximity to the area of building and the source of supply of the 10cm to 20cm diameter hard weathered stones which when fired make the best nourah. The nourah-stones are found at the foot of the jebble. The dry branches and shrub wood used for fuel was also collected on or near the jebble. Since access to the mountains has been restricted by the political-military situation the indigenous nourah firing industry has all but collapsed. Quarried limestone scraps have also been fired to produce lime but this system is not as efficient as the firing of the hard nourah stones. There is more wastage and a higher proportion of cinder according to one of the old kilnmen.

Procedure of Nourah Production:

The stones are brought to the kiln on donkey back (from the jebble). The kiln (Fig828) is basically a pit about 3.0 meters deep and 2.5 meters wide with a limestone wall built up 1 meter above ground level around it. Near one side of the pit another smaller pit is excavated with stairs running down to the base where a hole is dug through to the larger pit; this serves as a firing hole.

Firewood fuel is laid in alternating layers with the nourah stones, the larger stones being in the layers at the bottom of the pit. The fire is then ignited and stoked through the firing hole at the base and is maintained for about 24 hours. The whole pit is then covered over allowing slow burning and' finally cooling. After about 2 weeks time the pit contents are dug out and carefully sifted, using screens, the nourah being separated from the cinders and charcoal. Good stones will apparently produce 2/3 their volume in nourah the rest being cinder.

Small bits of high quality charcoal are by-products of this system and are sold for use in silversmiths' burners.

The finished nourah is mixed with sand and water and used as a paint wash on walls. A thicker mixture of fine sand and nourah is used' as plastering or rendering. This mixture adheres better and lasts longer than cement according to local people talked to.. Since access to the basic materials is now restricted, imported gypsum is now being used.

8.3.3.3 Roof Construction

The construction of the roof is always the most difficult problem in house building. This seems to hold true in most parts of the world.

Where limestone is a heavy material taking only compression its use in Oman seems to be limited to walls of the load bearing type. Limestone can be used, on the other hand, as a roofing material if it is employed in the construction of vaults. These vaults can be designed to exert only compressive loads (taking parabolic cataline configuration.)

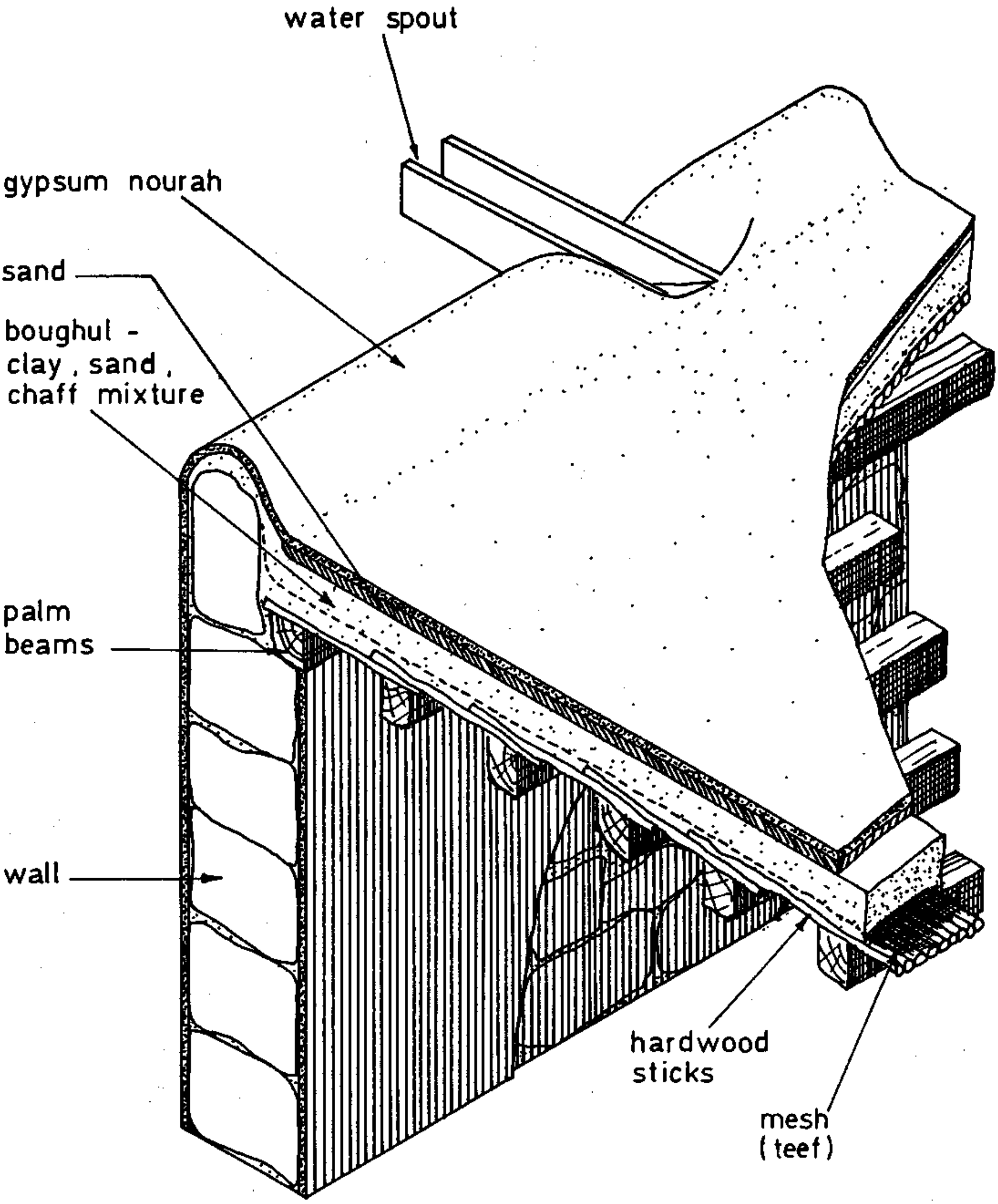
The rooms of the limestone houses of the Salala region are predominantly flat and therefore employ materials other than limestone. Although there were a number of roofing systems employed, the roofing technique which occurs often in the existing town houses in Salala is described here. (Fig829) This same construction is also used as flooring in multi-story buildings.

Split coconut palm beams 10 - 15cm in diameter spanning approximately 3 meters and at 30 - 35cm centers form the basic structure. Over these are laid short hard wood sticks (from mountain trees) closely set perpendicular to the beams. On this a wet fibrous layer (tee) is put down, this is usually a mesh like material collected from the crown of the palm, (occasionally cloth is used). A mixture (Boghul) of red sand clay with chaff or seed casings from a plant called Byr and water is fermented for about 2 weeks beforehand and applied over the mesh (leef. The (boghul) layer is about 15 to 20 cm thick. Several fibrous (leef) layers may be incorporated into the (boghul) layer to provide,extra integral reinforcing. Another thin layer of sand is put over this and then the construction is sprayed with water to encourage binding between the layers. The surface is then heavily pounded with a log to force out the water and encourage adherence of the layers. In some of the wealthier houses a layer of gypsum plaster (nourah) is applied in addition.

Although these roofs are predominantly flat they are always well drained, having an appropriate inclination, sloping to spouts which drain water away from the walls. These roofs do require maintenance and inspection especially after each rain when they are re-pressed or rolled with a heavy roller.

The (boghul) sand, clay and chaffrmaterial apparently has excellent properties in roofing. It has been reported that it holds together like cement but it never cracks in the heat of the sun and apparently never lets moisture through. Thermally it is also much superior to modern roofing solutions such as reinforced concrete slabs because the mud has a high insulative value (see heat transfer charts for. comparison.)

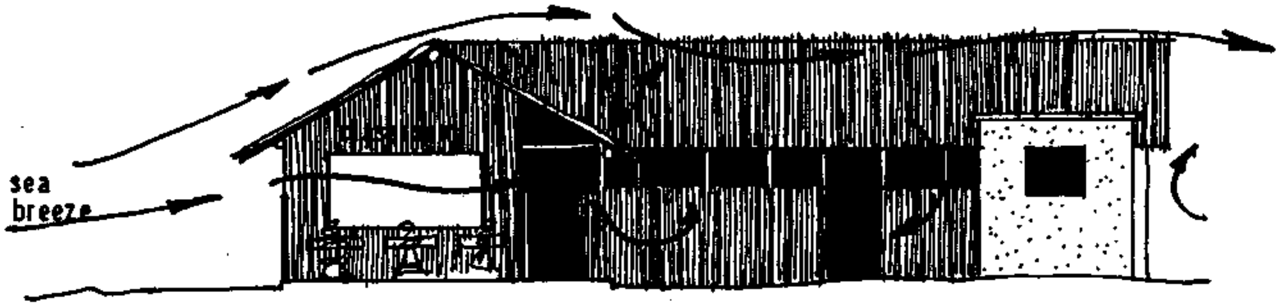
With access to hard wood from the mountains restricted details of this type of roofing must be modified. The local production of palm beams can not keep pace with the sudden rise in the demand for wood. Due to these factors wood and plywood is now imported. New roofing details involve the use of 3" x 4" beams with 1/2’’ plywood, a sheet of roofing felt and a cement coating. According to the local inhabitants this new type of roofing is inferior to the indigenous system described above in its durability and strength and its insulative value.



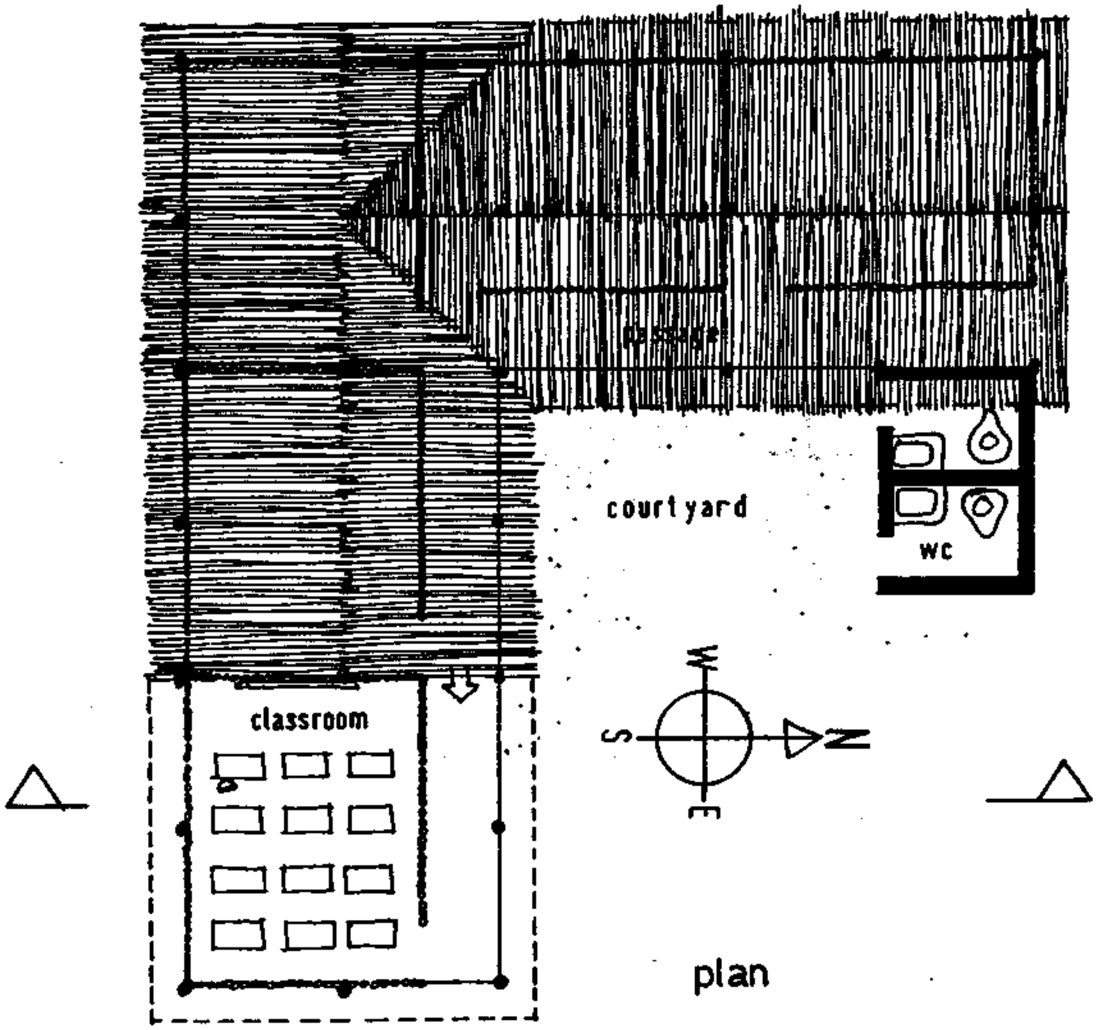
Roof Section

Fig. 829

Barasti School · Salala   Built by Government 1973



section   note natural
ventalation system



plan

8.3.3.4 Coconut Palm Frond Stem (Barasti) Construction

The Barasti used in Salala is quite different from that used in the north on the Batinah Coast. The barasti in Salala is from the coconut palm as the date palm does not grow in the region. The coconut palm is much more leafy than the date palm and the frond stems are shorter and taper very quickly. While date palm barasti is used in pre-assembled panels in an almost prefabricate system, the coconut palm barasti requires more of a built-in place method of construction. Walls of coconut palm barasti are not self supporting in themselves as the date palm barasti panels are, but require hardwood posts or some other supporting member be incorporated into the wall to provide rigidity.

Construction of a Barasti Room

The dimensions of the room to be built are plotted out on the ground and the corners are established with heavy wooden (hardwood or palm) posts, which are dirven into the ground. Long posts are set at centre points of the end walls to eventually support the roof ridge beam which will run between them. At intervals of about 30cm along the length of the wall smaller diameter posts are likewise driven vertically into the ground. Thinner horizontal members, either barasti stems or hardwood sticks are tied to the posts to form a lattice framework (Fig 830). This lattice is tied so that .a cavity is formed between pairs of horizontal members (Fig 831).

Coconut palm fronds (barasti) with leaves on are collected. These stems are inserted into the cavities formed between the horizontal members, and form the substance of the wall (Fig 832 & 833). With the walls completed the roof structure is assembled. A long hardwood beam is tied horizontally between the two end posts which will support the roof. These supporting posts are often naturally forked at the point that the ridge post intersects.

Aside from these posts and ridge beam the basic roof structure is assembled on the ground before errection (Fig 834). The structure is a basic lattice of wooden sticks and barasti stems loosely tied together. It can be easily hoisted into position on the roof by two men and some ropes. The lattice is tied to the ridge post and the supporting walls, and then post tensioned by pulling all the ropes taut. (Fig 835).

Palm stems with leaves left on are tied to the lattice, once it is tied firmly in place. The leafy stems are tied so that the tips of the leaves point downward, and each successive layer is tied overlapping the previous one using the same principal as thatching or shingling. This arrangement facilitates water sheding.

The room is then complete, unless the owner chooses to render it with mud or some other material such as gypsm. Rendering material is applied directly to the wall surface, which has previously been moistened. No lathing is necessary because the barasti leaves provide an excellent roughened surface for the plaster to adhere to.

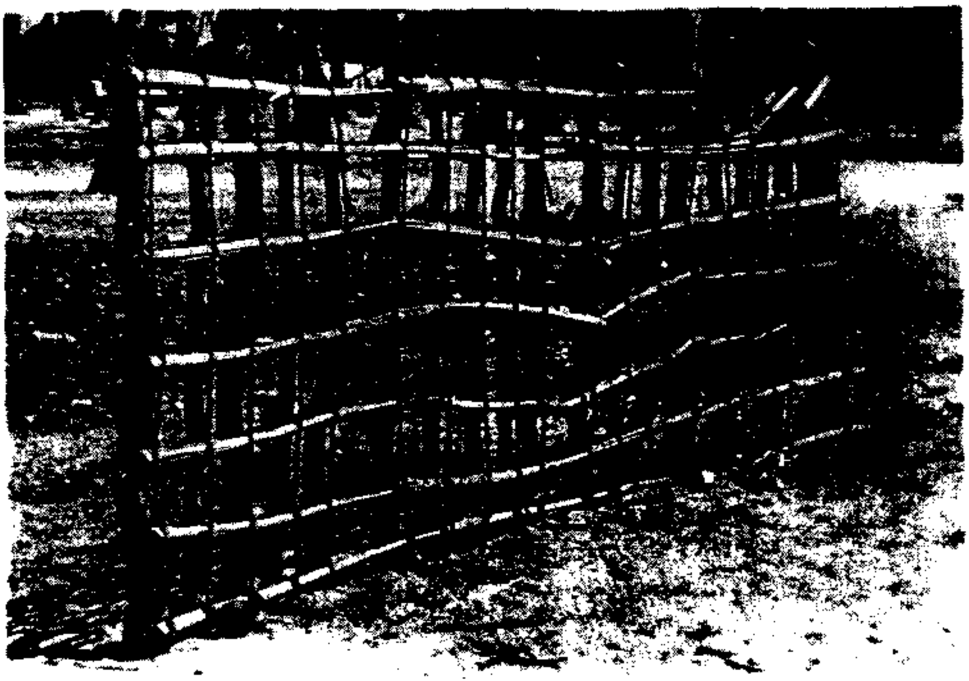


Fig 830
Hardwood posts are driven into the ground and horizontal members are tied across

Fig 831
Detail showing system for tying basic structure together

Fig. 832
Coconut palm frond stems (barasti) are inserted into voids in structure

Fig. 833
Section showing barasti wall panel

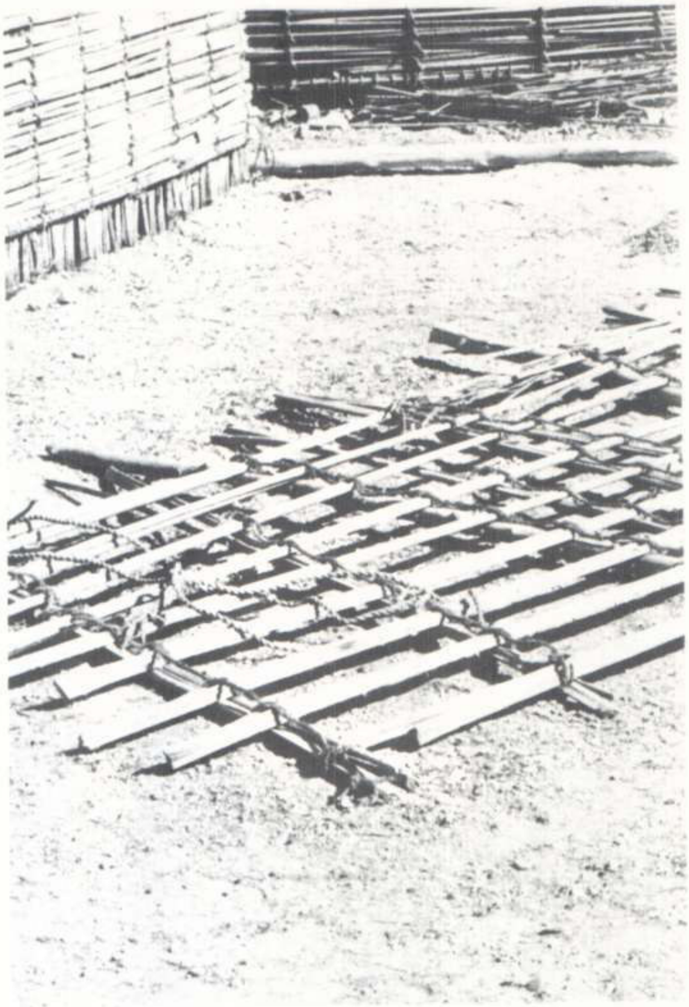


Fig. 834
The basic roof structure
is pre assembled
on the ground

Fig. 835
The roof is post tensioned
and tied when in place

Barasti house
using mud to
stabilize openings

Detail showing
mud plaster on
a barasti wall

Interior of mud plastered
barasti house

8.3.3.5 Availability and-Economics of Materials

The economy of the Salala area is subject to a very high rate of inflation. A few years ago a man could build himself a house for approx. 250 R. where now the same house could cost him over 10,0008. (1) Three years ago limestone cost 3 Rials/100 but now it is in the 25-30R/100 range. (2) (fall 73)

Cement blocks on the other hand costs 20R/100; a bag of cement costing more than 1.508. It is interesting to note that most of the cement used in Salala is imported from Pakistan where it can be purchased for the equivalent of approximately 0.300R. (2).

A house can therefore be built somewhat cheaper using cement block rather than limestone. One must however consider that the money spent in limestone construction is spent in the Salala community and therefore continues to circulate in that community aiding in its development, whereas much of the money spent on concrete is exported and is lost to the community. Limestone is considered among the inhabitants to be better than concrete in that it is stronger, lasts longer, is thermally superior (see charts) and can be reused time and time again. As said earlier a method to reduce the cost of quarrying the limestone must be found. This will become more and more urgent as the price of cement is rising astronomically on the international market.

Labour too has increased in cost. Where a master mason a few years ago earned 0.5 Rial/day he now earns about 4.0 Rial/day. An assistant or apprentice to the mason who may work as a mixer earns 2.5 Rial/day and a site labourer may make 2.0 Rial/day. Imported labour generally from Pakistan or India is the most poorly paid at little more than 1.00 Rial/day. (3).

For a basic two room house on a plot 20m X 20m surrounded by a perimeter wall one would require 8500 stone blocks costing about 2500R for the stone alone. One man interviewed had just completed a new concrete block room measuring 6m X 3.2m at a total cost of 4508. He had previously built with his own hands a similar sized barasti house with very little money. He said that he built with concrete because he was poor and could not afford stone. If he gets more money he will build the rest of the house in stone because it is stronger and cooler in summer. This man worked for the municipality and was earning about 30r/month. A similar sized room built in stone would cost about 800R. This figure could be lower if the structure was owner built or higher if contracted.

Wood

Coconut palm wood when available is the cheapest wood for use as roof beams. A complete trunk about 20 meters yields at least 16 suitable pieces. Half split trunks, 3 meters long, cost one Rial each where as quarter split trunks of the same length cost 0.500R.

Timber imported from Dubai is now used extensively. 3" x 4" beams cost 3 Rials each. Thin plywood used over the beams costs about 5 Rials a sheet. The timber requirements for roofing: the 6m X 3.2m room described earlier on would be about 15 beams and 5 sheets of plywood.

Again it should be noted that prices of imported materials are rising rapidly and are already out of reach of a large part of the population. It seems that the only hope in rectifying this situation is to decrease the reliance on these imported goods and develop reliable local alternatives.

I Refererences from local builders and municipality employees.