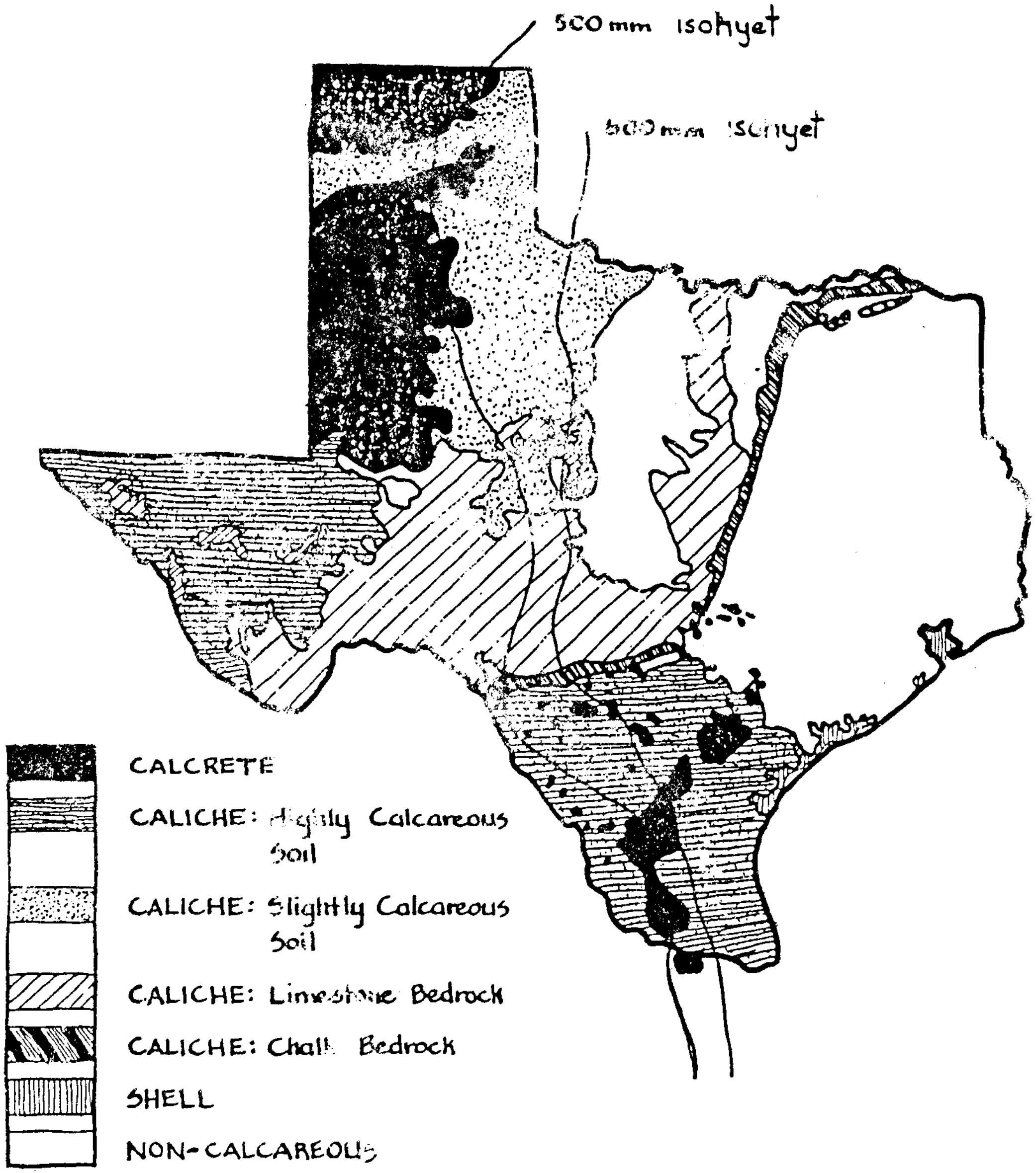
THE CALICHE REPORT

second edition



CALICHE DEPOSITS
in texas

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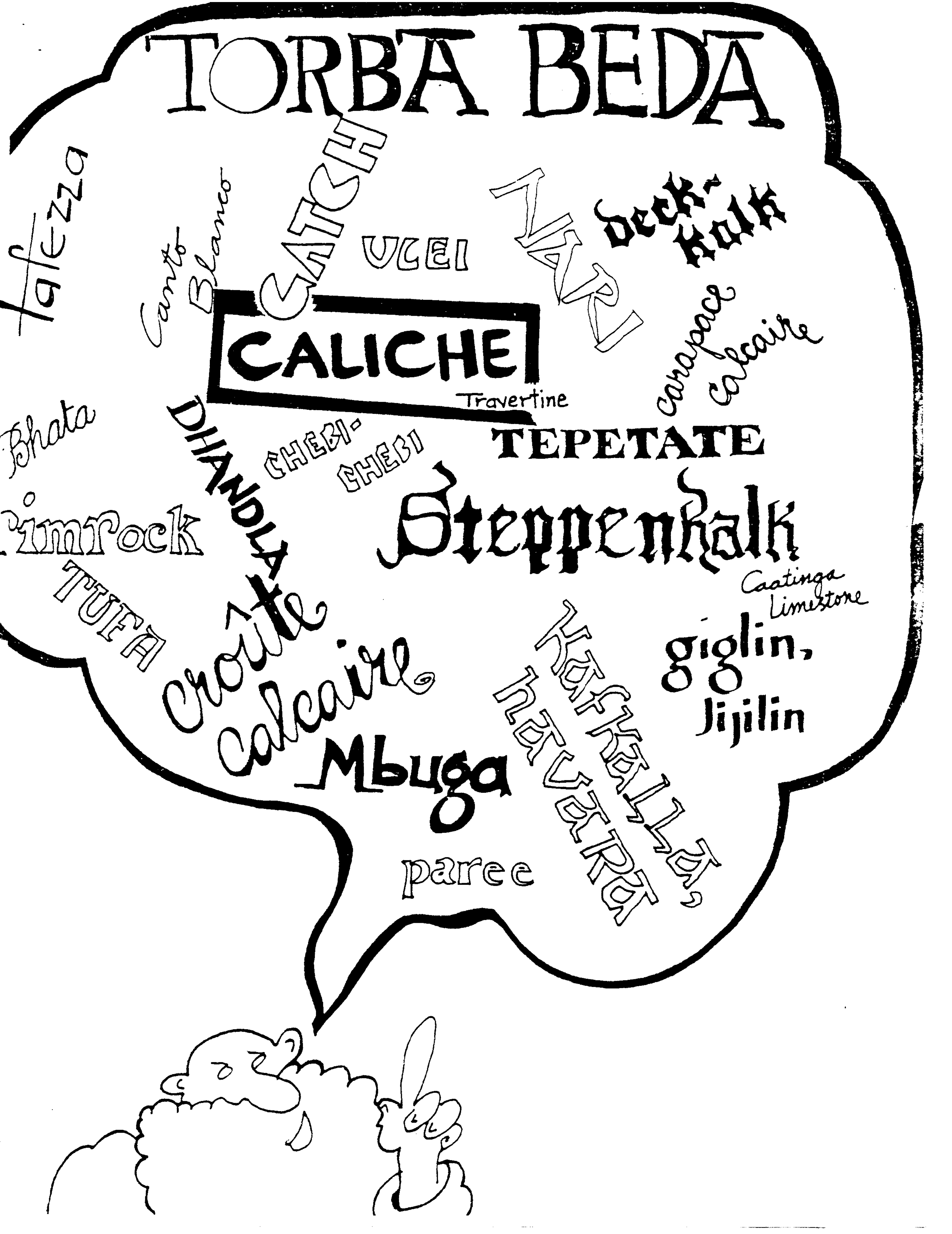
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Bhata
DHANDLA
CHEBI-CHEBI
TEPETATE
Steppenkalk
Rimrock
TUFA
croûte calcaire
Mbuga
Caatinga Limestone
giglin,
Jijilin
kafkalla,
havara
paree

THE CALICHE REPORT
second edition

The Distribution & Use of Caliche as a Building Material

Steven P. Musick

Center for Maximum Potential
Building Systems
Austin, Texas
April, 1979

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CALICHE REPORT

2nd Edition

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I. INTRODUCTION

1.1 Scope

The purpose of this discussion is to introduce calcium carbonate, particularly in the form of caliche deposits, as a practical masonry building material. The distribution and availability of caliche and other carbonate materials is investigated. The broad distribution and abundant supply of caliche in Texas are the most important aspects of calcium carbonate technology. The report outlines the basic qualities and attributes of unfired masonry materials, and shows the information and techniques necessary to use caliche according to these criteria. Current technology in forming, equipment, production schemes, and labor requirements is discussed and illustrated with examples. Physical and engineering data is presented for comparison to other unfired masonry construction modes. A Resource Section is provided listing regional resources pertaining to caliche, including information, equipment, materials, and contact persons. Finally, published and unpublished material referred to in the text is compiled along with additional publications for those interested in more detailed investigation of the subject.

1.2 History

Caliche is used extensively throughout western and central Texas as a road base material and as a raw ingredient in the production of cement and lime; however, there are only a few references to the use of caliche in building construction. Indurated or rock-like caliche has been quarried and used as building stone in South Texas[1]. In Wheeler County there are several structures built with stabilized caliche. One such structure was 35 years old in 1945 and showed no cracks at that time. [2]There is a Texas A & M publication which presents some of their stabilized caliche work in West Texas in the 1940's[3]. Their research included actual construction of a stabilized caliche building.

These early attempts at stabilizing caliche were extensions of the research into soil cement building modes. Soil cement research grew out of the developing science of road building, the housing problem in the United States associated with World War II, and the need for low cost housing in less developed countries. Soil cement refers to the stabilization of a soil or earth material with cement. The stabilization of soils with other agents, such as blood and dung, has been practiced throughout the world for centuries.

Our experience with soil cement and caliche building modes over the last 5 years suggests that caliche has tremendous potential as a low cost building material for a large part of Texas. Caliche is a predominantly carbonate soil deposit found extensively in the Panhandle, West, Central, and South Texas. Caliche is easily accessible and readily available. It has been mined in many places for roadbed material and it can be acquired from suppliers in many areas. Caliche building techniques are simple and based on the well established technologies of soil cement. Our research here at the Center for Maximum Potential Building Systems (CMPBS) demonstrates that caliche building materials are strong, durable, inexpensive, and possess useful thermal characteristics.[4]

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1 personal communication, State of Texas, Department of Highways & Public Transportation, 1976, Plate 9
2 Harrington, 1945
3 personal communication, Mike Garrison, 1978.
4 see Plates 3 & 4 in Appendix B for a brief introduction and summary of earth work at the Center.

1.3 Design Potential

Why build with caliche? Let's start with a concept, known as Passive Solar Design. This concept concerns the design of a building in such a way that the structure reacts with the changes in the outside natural environment to produce a comfortable microclimate within the building. There are several design features which allow the building to let the outside environment in when it is advantageous and shut it out when it is not. Some examples are: orientation of the structure with respect to winter sun and summer breezes; roof overhangs for shading; size and orientation of windows to optimize direct gain of solar heat; earth/air heat exchangers; and the placement and timing of ventilization. Another effective strategy is the use of high mass building materials in order to store heat and buffer temperature changes in the outside environment.

Earth is a good choice for a high mass building material for several reasons. Earth or soil has the mass needed to achieve good thermal characteristics in a wall. Earth is almost universally available. Suitable earth material may be found on the building site or may be available locally. Earth is a low cost, labor-intensive material, and lends itself well to simple technologies and construction techniques. Consequently, important economies are achieved in the operating costs usually associated with maintenance of thermal comfort.

Development of a building material constituted largely of caliche and sand should be of interest throughout large areas of Texas as these are common resources in a region where the soils have generally been considered unsuitable for use in traditional, low-technology earth building modes such as adobe. These building modes offer many advantages due to the variety of functions provided by a single material: structural support, division of space, fire and weather protection, rot-proofing, and thermal and acoustical insulation[1].

1 Taylor, 1976

II. CALICHE

2.1 General Discussion - Caliche

There are three major forms of caliche occurring in nature: Bedrock - including limestone, dolomite, chalk, calcarous clay and sand, and carbonate sediment; Soil - consisting of calcrete and caliche; Biological Sources - including shells of molluscs, such as oysters and clams. Soil calcium carbonate is generally the most desirable form, in terms of its particles size, sand content, and accessability. Because of the confusion about the terminology of soil calcium carbonate, the popular term "caliche" will be used to refer to soil with any amount of calcium carbonate present. The percentage of calcium carbonate is roughly described as slightly calcarious, calcarious, highly calcarious, or as calcrete. The category is determined by the amount of induration or hardness of the material, and the material's ability to fizz in a 10% solution of hydrochloric acid[1]. Calcrete as used here and as suggested by several workers in the field[2] refers to a completely indurated calcium carbonate accumulation generally formed in the lower soil horizons and containing a high percentage of calcium carbonate[3].

Caliche can be described as a predominantly carbonate soil deposit of exceedingly variable chemical and textural composition. Caliche is most often associated with the lower soil levels, i.e., the lower B and the C horizons, but often builds to the surface or is exposed by erosion. Caliche thicknesses range from a few feet to forty feet with fifty foot thicknesses found in some High Plains depressions. Even greater thicknesses are found in some arid basins of the western United States[4].

---

1 The Carbonate Residue Test listed in the Manual of Testing Procedures by the Dept. of Highways & Public Transportation - State of Texas.
2 Goudie, 1973
3 ibid
4 ibid; Reeves, 1970

2.2 Caliche Formation

There are several models of caliche-calcrete formation. The three basic models are:[1]

1. In Situ weathering of carbonate bedrock
2. Secondary Precipitation in the middle and lower soil zone.
3. Primary precipitation from surface and subsurface waters saturated with calcium carbonate.

In Situ weathering and Secondary Precipitation are the predominant processes, but no one process operates to the exclusion of the others. In Situ weathering occurs with the chemical and mechanical breakdown of the carbonate bedrock into finer and finer soil particles with time. Secondary Precipitation operates through two different processes, both occurring in arid to semi-arid climates. One model involves water from intermittent rainfall leaching down through the soil, dissolving calcium carbonate at or near the surface and redepositing it in the lower soil horizons. This model allows for caliches to build toward the surface as the lower soil zones become plugged with calcium carbonate filling the pore spaces. The other model requires upward movement of water through the soil by capillary rise due to evaporation at the surface. Calcium carbonate present in ground water or dissolved at the lower soil zones moves upward through the soil and precipitates out in the middle and upper soil horizons. The leaching model is more widely accepted, as it can account for the large accumulations of caliche found in many arid basins; and also for some of the micro features exhibted in the lower soil horizons of well developed caliches. See Figure 1.

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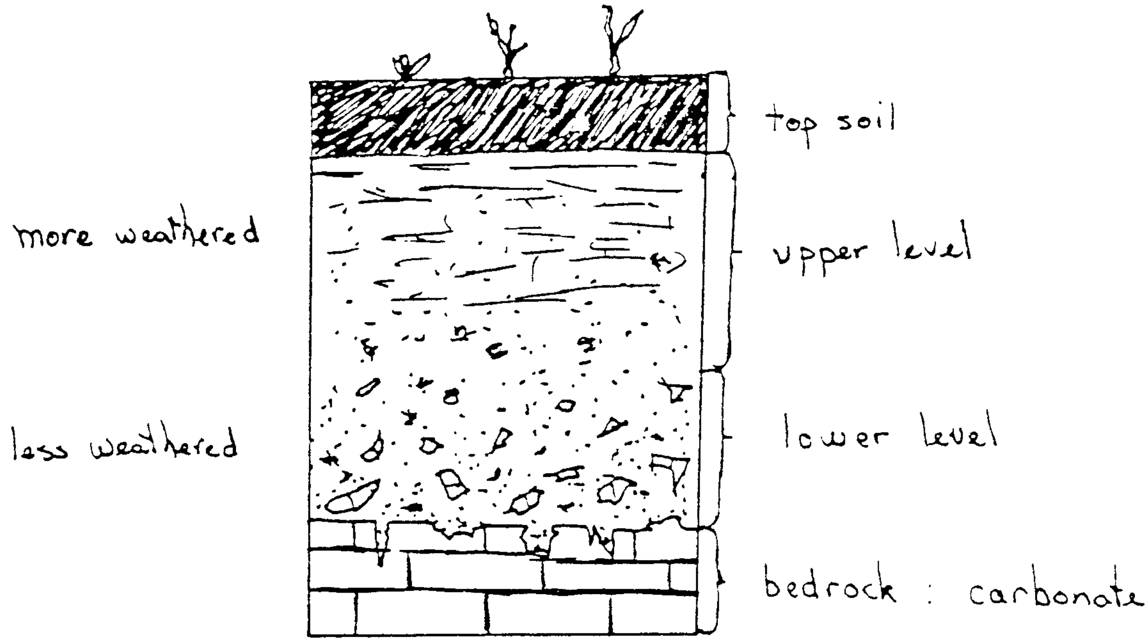
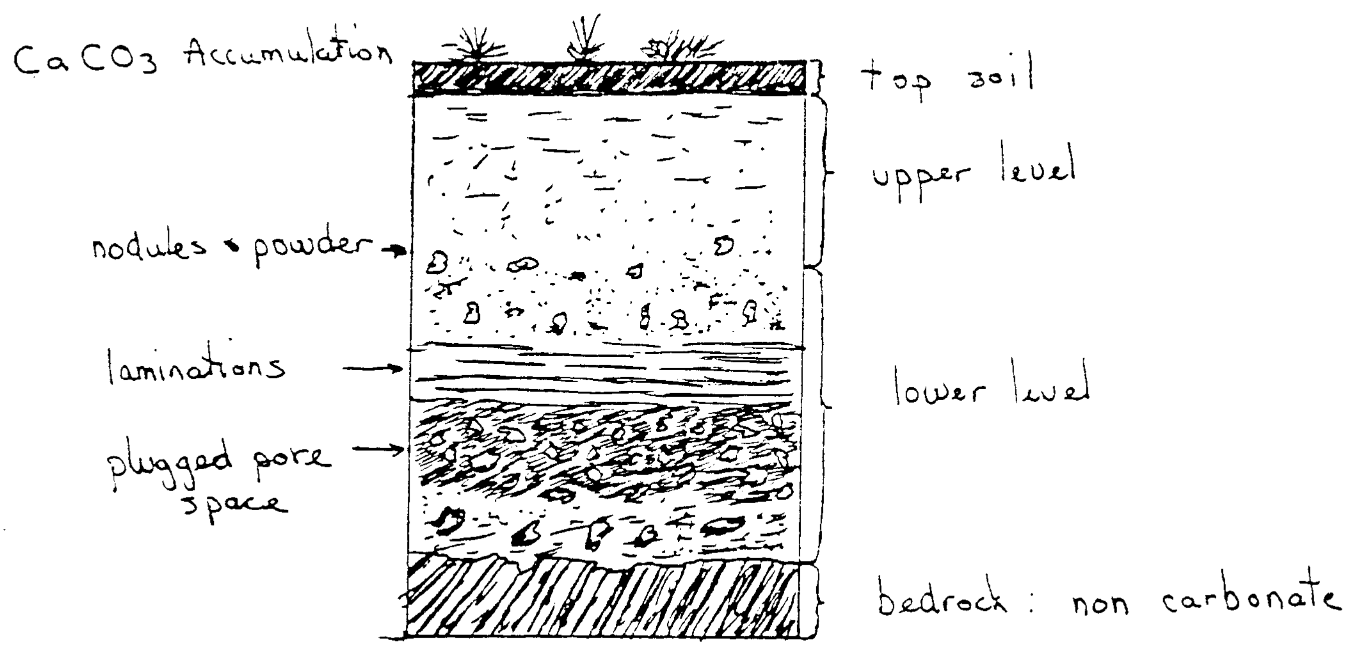
1 The discussion of the formation of caliche is condensed from a more detailed description of the models of caliche formation in Goudie, 1973.

Caliche Formation



In Situ Weathering: chemical & physical breakdown of carbonate bedrock — Edwards Plateau



Secondary Precipitation: Calcium carbonate dissolved in upper level, leached down, & precipitated in the lower soil level — Southern High Plains

FIGURE 1

Extensive calcretes produced by secondary precipitation seldom occur in climates wetter than 20-24 inches (500-600 millimeters) mean annual rainfall[1]. However, Reeves, 1970, shows that other climatic and physical factors are important, and may cause calcrete formation in wetter climates. Additionally, the In Situ weathering process will form caliche in areas where rainfall may exceed 30-35 inches per year. A regional example of this occurrence is the Edwards Plateau of Central Texas.

2.3 Caliche Chemistry

The chemistry of calcium carbonate soils varies considerably. Calcium carbonate accumulation is often associated with silica, magnesium carbonates, iron and aluminum compounds, and traces of other compounds including those of sulphur. Following in Table 1, Aristarain[2] cites several regional caliche chemistries, which give some idea of the general constituents and variations in caliche deposits from the Southwest. These chemistries can be compared with those listed in Tables 8-12 in Appendix A. Tables 8 & 9 show calcrete chemistries from several areas of the world, while Tables 10 & 11 compare caliche chemistries in the High Plains of eastern New Mexico. Table 12 contains two chemical analyses of a carbonate deposit located near the town of Mountain Home in Central Texas.

In terms of the textural makeup of carbonate deposits, very little information is available. Here at the CMPBS in Austin, Texas, we have performed some textural analyses on two caliches and the carbonate deposit from Mountain Home. The results of these analyses are listed in Table 14.

---

1 Goudie, 1973.

2 Aristarain, 1970.

TABLE 1

Chemical Analyses of Samples of Caliche from the Literature

Constituents	Analysis No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	......	3.47	0.05	22.30	9.72	74.84	7.88	24.54	27.28	31.02	32.16	35.62	42.24	42.30
Al_2O_3	......	0.99	......}	0.42	......	......	{0.45	1.68	2.62	1.00	1.94	0.95	2.03	1.21
Fe_2O_3	1.88	0.97	0.85}		......	......	{0.36	1.22	1.36	1.14	1.14	1.07	1.29	1.65
FeO	Nil	......	......	......	......	......	......	......	......	......	......	......	......	......
MnO	......	Tr	0.13	......	......	......	None	None	Tr	Tr	Tr	None	Tr	Tr
CaO	......	......	54.15	40.19	......	......	49.31	39.02	36.81	35.57	34.31	20.41	27.22	29.41
MgO	......	0.24	0.87	0.14	......	......	1.88	1.12	0.80	1.00	1.16	13.40	2.18	0.88
Na_2O	......	......	0.18	......	......	......	......	......	......	......	......	......	......	......
H_2O-	1.20	0.51}	0.15	......	......	......	0.99	1.38	{......	......	......	......	......	......
H_2O+	......	0.77}		......	......	......			{2.35	1.43	2.44	1.54	1.90	1.40
P_2O_5	......	0.26	0.12	......	......	......	None	None	Tr	Tr	Tr	Tr	Tr	None
CO_2	......	......	42.15	31.58	......	......	39.00	30.94	28.74	28.40	26.81	27.20	22.62	23.24
SO_3	......	Tr	0.28	0.14	......	......	None	None	None	None	None	None	None	None
Ign. loss	......	......	......	5.87	......	......	......	......	......	......	......	......	......	......
Others	......	......	0.99	......	......	......	......	......	......	......	......	......	......	......
$CaCO_3$	78.28	67.71	......	......	79.16	22.03	......	......	......	......	......	......	......	......
$MgCO_3$	2.13	24.91	......	......	8.02	0.01	......	......	......	......	......	......	......	......
$CaSiO_3$	5.57	......	......	......	......	......	......	......	......	......	......	......	......	......
Al_2SiO_5	7.37	......	......	......	......	......	......	......	......	......	......	......	......	......
Total	96.43	99.86	99.92	100.61	96.90	96.88	99.87	99.90	99.69	99.56	99.99	100.19	99.48	100.09

Sources.—(1) From Southern Arizona, U.S.—J. S. Mann, analyst (Blake 1902); (2) from Acacia, eight miles west of Broken Hill, Australia—Mingaye, analyst (Mawson 1912); (3) from Buliba-ba, Mexico—F. Roel, analyst, Instituto Geológico Mexico, 1913, transcribed by D. Graf (1960, pt. 4.4); (4) from Lubbock, Texas, U.S.—T. E. Stallken, analyst (S hoe caliche"; and (6) "Sandy caprock" from Miami, Texas, U.S.—R. M. Ishai 1931); (7–16) from Texas County, Oklahoma, U.S.—S. G. English, analyst

Source: Aristarain, 1970

Textural analysis here refers to granulometric analysis or particle size breakdown, in combination with certain standard soil tests including the Atterberg Limits and shrinkage tests. Particle size is important in determining the building potential of an earth material. Goudie[1] has developed a graph indicating that the silt and clay content of a soil increases with increasing amounts of calcium carbonate. This could be a very significant relationship, because of the importance of particle size in the stabilization process, which is explained in the next section.

2.4 Regional Distribution of Caliche

Regional distribution of caliche in Texas is shown on the map in Plate 1. Soils in Texas vary widely in percentage amounts of calcium carbonate and in the physical occurrence of caliche deposits. Calcrete in the Southern High Plains of the Panhandle (Ogallala Formation) and in South Texas (Reynosa Formation) are thick, starting at a few feet in thickness and in depressions up to fifty feet. They are either partially or completely indurated and contain a high percentage of calcium carbonate. Other areas of significant caliche accumulations are West Texas soils and the soils and some lime or chalk-like deposits in the Edwards Plateau. Generally, caliche can be found, at least in patches, everywhere west of the Balcones Escarpment running through Central Texas.[2]

The following map was put together from information provided in the references cited below[2], from geologic maps, land resource atlases, and mineralogic atlases published by the Bureau of Economic Geology in Austin, Texas;

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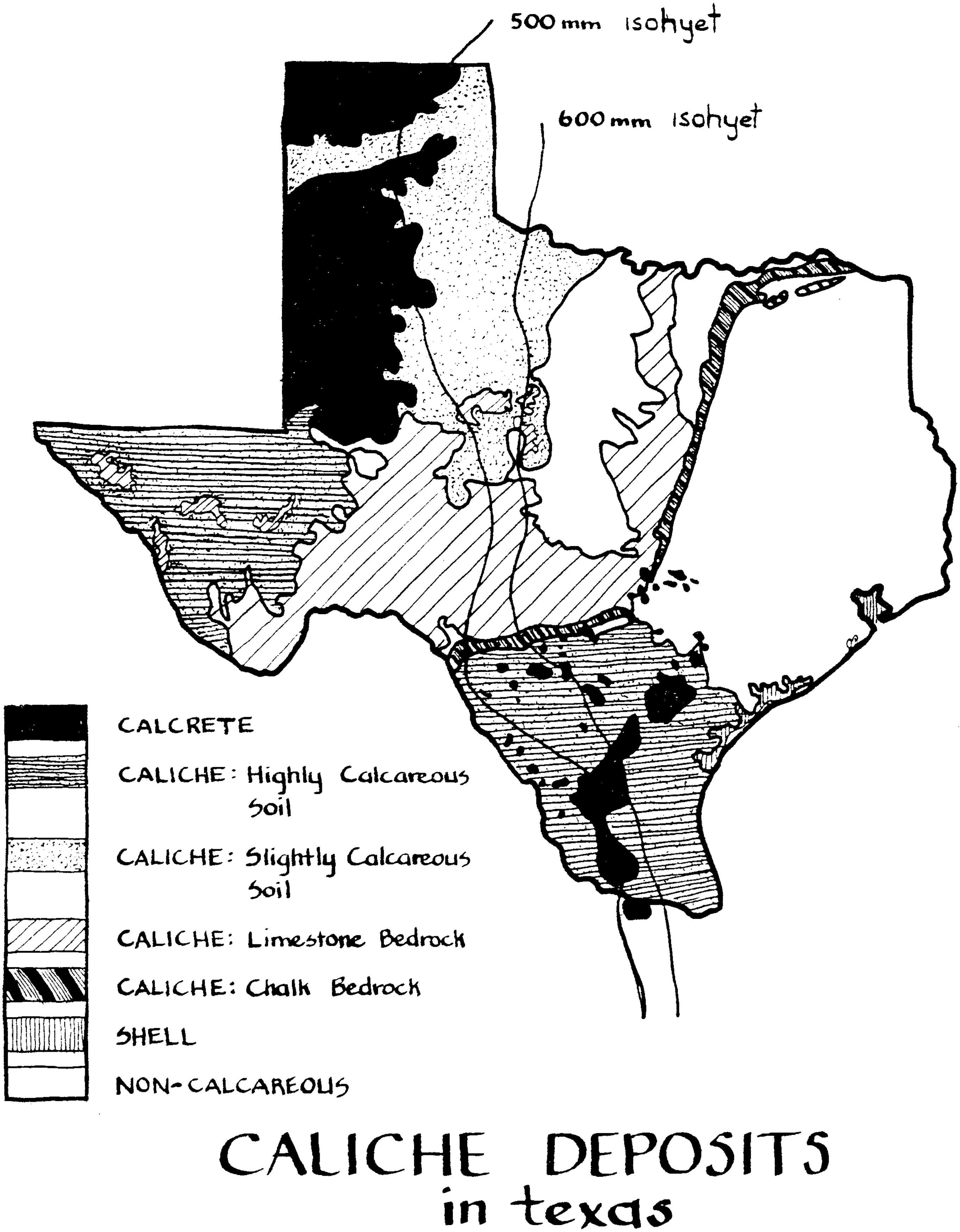
1 Goudie, 1973.

2 Goudie, 1973; Reeves, 1970; Price, 1940; and Arbinghast, 1973.

and from soil survey maps of the state of Texas published by the United States Department of Agriculture in cooperation with Texas A & M University. In Appendix B there is an older map showing caliche distribution on a county by county basis on Plate 5. This map includes other forms of calcium carbonate and counties where production occurred in 1943.



CALICHE DEPOSITS in texas

PLATE 1

III. SOIL STABILIZATION

3.1 Shrink/Swell Reaction

The major construction problem with earth materials is their shrink/swell capacity. The shrink/swell phenomenon is specifically related to the clay size fraction (200 microns or less in diameter) of the material and is referred to as colloidal particles. The shrinking and swelling of the material is accomplished by the easily reversible absorption and release of water by the colloidal particles. This action is related to the electrostatic forces and surface/volume ratio peculiar to those very tiny particles. This causes plastic behavior under stress and results in low strength. In order to produce good building properties in earth materials it is necessary to: stabilize the colloidal particles, i.e., inhibit the absorption/release of water; bind the material together; increase the internal friction of the soil particles, i.e., the strength; and increase the resistance of the material to erosion.

These actions may be accomplished by stabilization and cementation. Stabilization is the inhibition of the shrink/swell reaction. Cementation is the property of binding, resulting from interlocking grains or fibers, or some form of molecular attraction. Clay, cement, lime, and lime/pozzolan mixtures are a few materials that exhibit binding properties.

3.2 Model of Stabilization

A good construction material is the result of the stabilization of a proper mixture of clay size and sand size soil materials. A good soil mix for soil cement should contain roughly 60% sand and 40% clay.[1] A mixture may be stabilized through chemical or mechanical means or a combination of both. Cement is an example of chemical means while rammed earth is an example of mechanical means. The mixture and stabilization can be visualized in this way: the sand portion serves as a framework giving structural support; the clay acts as the major binding material, filling the void spaces between the sand grains; it is also responsible for most of the internal friction or strength of the material due to its very small particle size; the cement coats the fine clay particles, inhibiting the shrink/swell reaction. The cement further fills the void spaces and forms its own binding network of hairlike fibers[2]. Compaction reduces void space and increases the internal friction of the material.

3.3 Stabilization of $CaCO_3$

Calcium carbonate stabilizes in a slightly more complex but ultimately more useful way. Calcium carbonate, when mixed in specific proportions with one of several chemical stabilizers undergoes a reaction in which carbon dioxide is given off. The colloidal particles during this chemical reaction are stabilized and not simply bound together, but fused. This is roughly analagous to fire hardened clay brick. If the mix is subjected to compaction the reaction is more thorough, and the resulting block is more fused and much stronger.[3]

---

1 Wolfskill et al
2 Double & Helawall, 1977
3 personal communication with Howard Scoggins, 1976.

IV. CALICHE DESIGN MIX

4.1 General Information

Good building qualities in earth and caliche blocks are: 1) strength, 2) low moisture absorption, 3) limited shrink/swell reaction, 4) resistance to erosion and chemical attack. The stabilizing agent is the most important factor in controlling the above properties of the mix. Proportioning the mix components and the use of additives are important in increasing the resistance of the block to chemical attack. Because of the variations in the compositions of earth materials from one site to the next, it is important to carefully analyze the chemical components and the textural makeup of the earth material. Then one experiments with the different stabilizing agents that are suggested by the analysis, by general knowledge of the earth material under examination, and local resource availability to determine the optimum design mix. An acceptable mix is based on a balance of good building qualities, practical workability, and the availability of materials, equipment, and labor.

The first step then after acquiring a source of caliche[1] is to determine its chemical and textural characteristics. The analyses can be made by the builder himself using information and tools developed by Howard Scoggins in the <u>Soil-Test Mini-Lab</u>[2], or he may have the material analyzed by a soil testing laboratory. There are two laboratories in Austin which offer a range of services, including design and testing, to the owner-builder and small contractor focusing on earth building materials. One is our lab here at CMPBS and the other is

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1 Locating a source is discussed in the Resource Section and in Section 4.5.

2 Scoggins, 1976.

Howard Scoggins' Earth Lab.[1]

An optimal caliche should contain 40-60% calcium carbonate with a wide range of particle sizes, but with at least 30% in the silt and clay size fraction. 40%-50% of the material should be non-carbonate, silica sand with most of the sand falling in the size range coarse sand to pebble size gravel (.5 mm to 10 mm; 1/50in to 3/8in). The caliche should contain little or no carbonate clay. A significant amount of non-carbonate clay would place the material in the category of soil cement, requiring slightly different techniques. The caliche should contain little or no organic matter. Decay of the organic material yields a gas reaction, which is detrimental to the strength of the caliche mix. Caliches, however, are seldom ideal in the pit. Analysis of the material will tell whether more sand of a particular size, or another more carbonate caliche is needed. In some cases, using a soil cement mode is more practical.

4.2 Stabilizers

The next step is the determination of which stabilizer is best suited for the material and its design uses, and the amount needed for a satisfactory mix. Our experiments to date have focused on three materials: lime, cement, and pozzolan (a fine grain, reactive silica material). Data on design mixes and variations are presented in Table 2 and Table 3. Specific stabilizers that we have used are: unslaked lime (calcium oxide), Portland Type I cement, and a combination of cement and pozzolan (volcanic ash). Pozzolan and hydrated lime (calcium hydroxide) is a combination we are presently studying.

---

1 See Resource Section.

Determining the amount of stabilizer to use is a more difficult problem. The alcock Shrink Test[1], which is used in the design of soil cement mixes gives only a gemeral, ballpark figure when working with caliche. The figure is often low, especially when lime is the stabilizer of choice. We have found that the best method is trial and error experimentation in certain percentage ranges for each of the stabilizers. The range for lime is 5-15% , for cement 5-10%, and for pozzolan/cement 7-12%. The method consists of making up test cylinders of the material with varying amounts of each stabilizer, and testing them for compression strength, moisture absorption, and surface hardness[2]. A few batches should determine the best mix balanced against the cost of the stabilizer.

There are advantages and disadvantages for each of the stabilizers. Lime is inexpensive, but presents some health hazards to workers breathing its dust. There is also some question about the long term strength of lime stabilized mixes, but there is no conclusive evidence either way. Cement is an expensive material and its production requires a large input of energy. However it produces the strongest block. Pozzolan is a plentiful resource in Texas, but no market exists for it at this time and so it is therefore unavailable in most areas. In terms of materials' cost and good construction qualities, we feel the pozzolan/cement combination is the best stabilizer.

---

1 Scoggins, 1976

2 See section on testing.

TABLE 2

MIXTURE EXPERIMENTS
DESIGN

Lime Stabilizer	
Samples A-C	Varying the proportion of sand and caliche, in an attempt to reduce the amount of sulphates in the final mixture.
D-F	Sodium hydroxide and sodium bicarbonate additives to improve stabilization and strength.
G-I	Varying the amount of quicklime stabilizer to determine the effects on strength and setting time in relation to costs of materials.
J-O	Sodium bicarbonate, sodium chloride, and cornstarch additives to test for improvement in strength and absorption.
P-Q	Varying the water content and material consistency to determine optimum setting times and ease of form removal.
LP_1-LP_2	Reduction of the amount of quicklime and an increase in the amount of caliche to check strength and lower costs.
Portland Cement Stabilizer	
PC_1-PC_3	Varying the amount of portland cement and the size of the sand aggregate to determine the optimum strength and absorption.
PC_4	Lowering the caliche/sand ratio to increase strength.
PC_5	Substitution of crushed limestone for course sand in the aggregate portion of the mix.
Pozzolan Stabilizer	
PZ_1	Addition of pozzolan as a partial replacement for portland cement to reduce sulphates, increase resistance to sulphate attack, decrease absorption, and reduce the cost of materials.

TABLE 3

MIXTURE EXPERIMENTS
RESULTS

Lime Stabilizer

Sample A-C	There is only a narrow range over which the sand/caliche ratio can be varied. A large percentage of caliche weakens the block, e.g. greater than 45%. This suggests that we can lower sulphates and keep good strength by maintaining a 55% sand to 35% caliche ratio.
D-F	Additives of sodium bicarbonate and sodium hydroxide produce generally unsatisfactory samples in terms of poor surface hardening and high cost.
G-I	These samples had the best strength and texture of this set of lime stabilized mixtures. Observations and tests indicate that more than 6-7% quicklime causes a loss in strength and a greater susceptibility to erosion.
J-O	Additions of salt and cornstarch produced totally unsatisfactory samples. Cornstarch is particularly difficult to work with and the samples show little or no cohesiveness.
P-Q	This set of samples indicated that the amount of water is in the mix is critical in terms of workability, initial setting time, and development of strength. Moreover, the critical range of moisture content is narrow being 14-19%. In practice the less water the better.
LP_1-LP_2	This sample is similar to sample H. This mixture however has a greater percentage of caliche. The LP series has the greatest strength of the lime stabilized samples. It has acceptable absorption, a moderately hard surface, and fine texture.

Portland Cement Stabilizer

PC_1-PC_2	There is a definite relationship between higher compression strength and a greater percentage of cement. There is also a complex relationship between the absorption and the particle size of the mix components. There is a reduction in the absorption with finer size caliche and coarser size sand.
PC_4	Increasing the sand/caliche ratio improves strength and allows a reduction in the amount of cement.
PC_5	Substitution of crushed limestone for chat produces an acceptable mix, but the absorption is increased and the strength reduced.

Pozzolan Stabilizer

PZ_1	These samples had a very fine texture, good strength, and excellent absorption, about 9.6%. However, the curing time is longer, i.e. about 3-4 weeks.

4.3 Moisture Content

The amount of water to be added to the mix is a critical question, more water equals a decrease in strength and erosion resistance. A good rule of thumb is: the less water the better. However, this rule must be balanced against the workability of the mix in the mold. Another factor which must be considered is the moisture content of the other mix components. Wet sand will have a significant affect on the moisture content of the final mix. Our experience in mix design suggests that the optimal moisture content for pressed blocks and rammed caliche is 8-10% with an acceptable range of 6-12%. A good field check is the Ball Test[1]. For poured caliche blocks the optimal moisture range is 15-20%. The mix should be as dry as can be easily managed in the molds. Table contains several caliche mix formulas that we have found to be successful.

4.4 Special Problems -- Sulphate Chemistry

There are some specific problems that arise when carbonate mixes are used as building materials. These problems relate to the chemistry of carbonates, their reactions and resistance to chemical attack. Various sulphates are the most important in their detrimental effects. Sulphates attack caliche mixes from inside as well as from the outside. The compounds which are most damaging are calcium sulphate (gypsum), magnesium sulphate (epsom salts), and sodium sulphate (glaubers salts). The entire chemistry is somewhat complicated, but the basic reaction occurs between the sulphates and free lime[2]. Free lime is calcium oxide which has not reacted

---

1 See Figure

2 For a more detailed discussion see Akroyd, 1962, Gauri, 1978, and Lea,

with other compounds during the curing or setting period. Free lime is present in Portland cement, quicklime, hydrated lime, and in carbonate deposits. Sulphates are found in all of the above in some amount and often in waters to which the caliche block is exposed. Another reaction occurs involving aluminum compounds in Portland cement.[1] There are two primary effects produced by these reactions. One is volume expansion, which causes disruption of the material. The other is conversion of the material to other compounds which are less strong or are soluble and removed by water.

Some approaches used to control the sulphate problem are: 1) reduction of the amount of free lime, sulphates, and aluminum compounds present in the stabilizers through the use of other additives in partial replacement of the cement of lime, for example pozzolan. Another alternative is the use of special Portland cements which contain lesser amounts of the detrimental compounds; 2) dilution of the free lime and sulphate percentage in the caliche material by increasing the sand/caliche ratio; 3) protection of the building from sulphate bearing waters; and 4) reduction of the porosity of absorption of the block through the use of finer size material.

4.5 Soil Sampling

Depending on your area, there may be several sources of caliche available. First check the building site. Using information and tools found in the Soil-Test Mini-Lab[2] and The Handbook for Building Homes of Earth[3], the building site may be field checked for soil suitable for earth construction. The basic procedure consists of

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1 ibid
2 Scoggins, 1976. Also see Plates 3 & 10
3 Wolfskill, et.al.

setting up a grid system for the site, so that the area may be covered completely, sample locations identified, and the extent of usable materials determined. Because of the amount of materials to be handled, a carefully executed soil survey will save time and effort later on[1]. The next step is to collect samples of sufficient size for testing purposed, e.g. 1/2 pound for preliminary tests and 2-3 pounds for further testing of the most promising samples. Samples should be bagged and tagged. A dirt auger is the best sampling tool, requiring less labor than a shovel. It is very important to collect the samples from the subsoil below the layer where plant matter and other organic material are present. Organic material is detrimental to soil cement and adobe. The decaying process produces a gas reaction which weakens the soil beyond limits for use in building. When collection of the samples is complete, then the first phase of testing can begin. Even if there is no caliche available on site, it may be acquired locally. Check in your area for caliche suppliers or for caliche pits. Often caliche is used by ranchers and road builders for base material. Be sure and test caliche samples from these sources before purchasing large quantities.

4.6 Testing Procedures

Three phases of testing are desirable for best results in earth material construction techniques. The first is the chemical analysis and the basic soil characteristics of the earth material to determine its suitability for stabilization. There are several basic

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1 See Section 5.3 on Materials Handling.

guides for the owner-builder and small contractor, which includes theory, a list of equipment, and step by step procedures[1]. Sources for testing information can be found in the ASTM Book of Standards and the Texas Highway Department's Manual of Testing Procedures.

The second phase involves testing the various experimental mix proportions for compression strength, absorption, and surface durability[2]. These tests will determine the final mix proportions. The third phase of testing involves quality control checks during block production. These tests are the same as those in the second phase, and serve to maintain block quality and pinpoint problems in the mixing operation. Tables 14 through 17 contain data from these various tests that have been conducted on some of the materials and blocks that we've worked with.

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1 See Table 6 Resources Section

2 Handbook for Building Homes of Earth, ASTM Book of Standards, Kern, 1972

V. FORMING - PRODUCTION TECHNIQUES

5.1 Molding Techniques

There are two modes of earth material construction: monolithic walls and molded blocks or bricks[1]. Additionally, two methods are applicable to each mode. The caliche mix in a moist state may be pressed or rammed mechanically, i.e., pressed block and rammed earth. The material in a wet state can be poured into molds adobe-style. Rammed earth construction consists of a slip form, similar to that used in pouring concrete, in which a layer of caliche mix is placed and tamped. (See Figure 3). Pressed blocks are produced by pressing the mix into a mold. A mold press can easily be constructed or one of several machines can be used[2]. Four such machines that are mentioned in the Handbook for Building Homes of Earth are the CINVA-Ram, Landcrete, Winget, and Ellson. Our experience is with the CINVA-Ram, a hand operated device which produces one pressed block at a time. (See Figure 2). The production rate is 200-300 block per day with a compressed strength of 900-1300 psi.

Adobe-style, wet caliche mix can be poured into forms of any shape and size. It can be used in a monolithic wall slip form, a block mold, a "sag" form, or cast in place as pipe or conduit (see Figure 2). The puddled caliche mix has several advantages over pressed block.

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1 A new process has recently been developed, whereby an earth material may be foamed. This process has great potential for simplifying block and wall production, decreasing the weight of blocks, and increasing their insulating value. Another exciting possibility being investigated now, is the application of concrete spraying technique,developed over the last 20 yrs., to caliche.

2 Wolfskill, et.al.

The mix is much easier to work with. The strength and durability of the block is excellent, as good or better than soil cement and adobe blocks. There is greater versatility in block sizes and molds. More block can be produced easier and faster using gang forms, without the need to use expensive machinery to press the blocks. However, there are a couple of good machines available that, with proper supporting equipment, will produce up to 1500 adobe size block per day[1].

Rammed Earth construction requires a higher level of skill than the two block techniques. The slip form must be constructed carefully of good materials, so that it can stand repeated use. The moisture content should be checked frequently with the Ball Test[2]. Care must be taken in distributing the soil material evenly in layers of the correct thickness for the size of the tamper, and in ramming the material evenly and consistently[3,4].

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1 see section on Equipment Schemes and photos on Plate 10.

2 see Figure 2

3 Wolfskill, et al.

4 See Plate 9 in Appendix B.

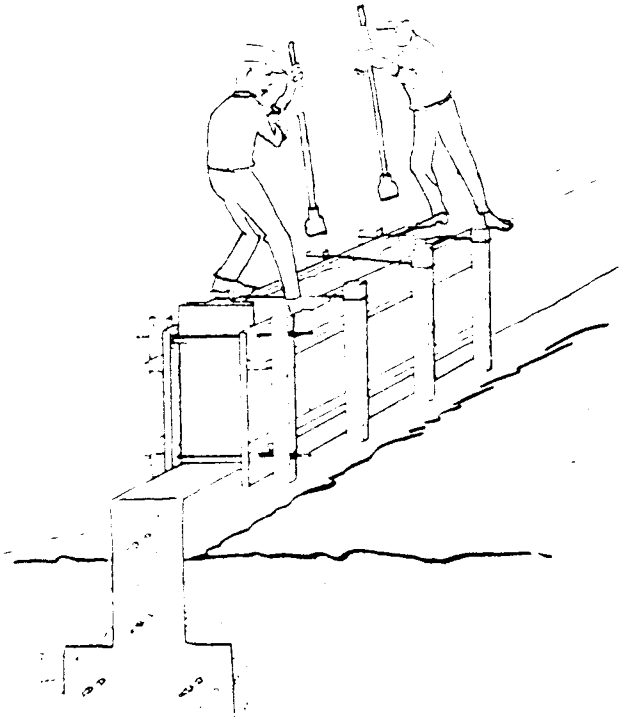
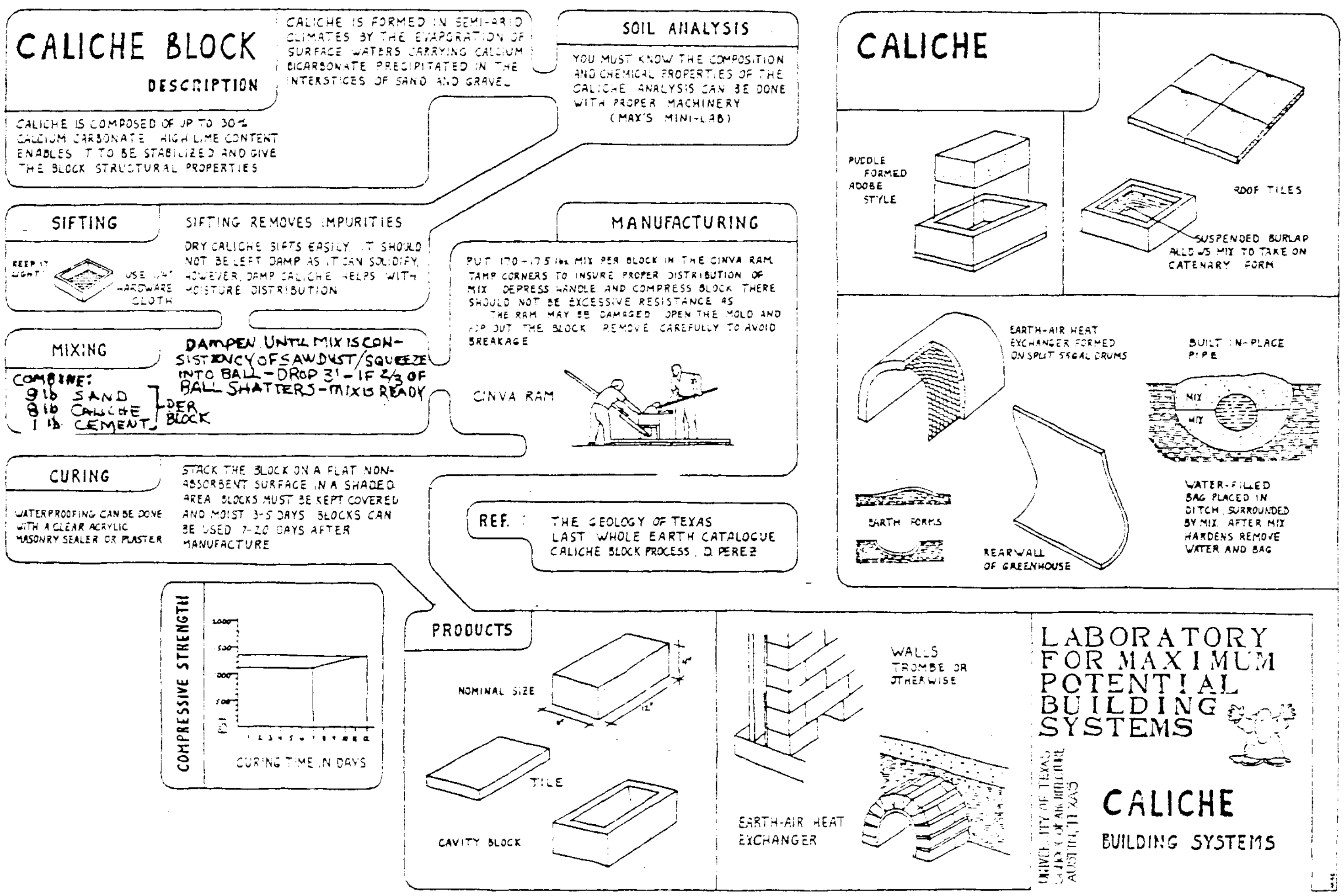


Figure 3
Rammed Earth Construction

Figure 2
Caliche Molding Techniques



5.2 Block Production - A General Scheme

1. Extraction of the caliche with bull dozer and/or front end loader.
2. Transport to production site in large trucks.
3. Dry the caliche material and control the compositional variation by spreading the material in a 6-12 inch blanket over a large area on the ground. The first layer should be allowed to dry in the sun for several hours before the next layer is laid over the first.
4. The material is then removed from the layered pile from one end so that material from each layer is thoroughly mixed.
5. This material is then sifted through ¼ or 3/8 hardware cloth or wire mesh. It may then be desirable to crush the waste and sift the material again.
6. Store the sifted material in a dry place away from moisture, so as to prevent clumping of the material and reaction with any chemicals in water.
7. Mix the components in a mortar mixer or concrete mixer according to the proper formula, keeping a constant check on the moisture content.
8. Lay a sheet of 4 mil plastic under the mold.
9. Lubricate the mold with a little water every 4 or 5 batches, or coat with an application of wax.
10. With shovel or wheelbarrow, dump mix into the mold.
11. Spread the mix evenly in the form. Shake the form to help the mix to settle into the corners.

12. After the form is filled, remove it by lifting it up - move on and repeat the procedure.
13. After 1-2 days the block may be rotated to their long edge for curing.
14. Blocks should ideally damp cure 4-5 days before stacking or moving. Blocks should cure (air dry) 10-14 days before transporting or laying in the wall.
15. The blocks need to be protected from direct sunlight for the first 5 days, and protected from rain during the entire curing process.

5.3 Materials Handling

One of the major aspects of earth construction is the handling of materials, especially in terms of labor, equipment, and space. The amount of material can be very large. A minimum of 15 tons of sand and earth for a small structure is not unreasonable. This amount of material is handled several times from the time of removal to the laying of block in the wall. The processing of this material will require a significant input of labor, time, and equipment. The first step is stripping the topsoil from the excavation area before the caliche can be removed. There should be little or no organic material in the caliche used to make blocks or walls. The excavated caliche is then transported, sifted, perhaps crushed, and stored in an area protected from moisture. The sand, caliche, and stabilizer are mixed and poured into forms. Blocks must have an area for curing, and then stored or transported to the building site.

Obviously the right equipment, coordinated labor, and sufficient area are needed for a reasonably efficient block production effort. Appendix B contains a letter from Heldonfels Bros. outlining the procedures used by a construction materials' contractor to obtain and process caliche material, and gives an idea of the equipment needed for a large scale, commercial extraction/production of good quality caliche. On any scale some equipment will be needed for extraction, at the least a bulldozer or tractor equipped with a shovel and a back hoe. If the caliche is purchased from a local supplier, a truck will be needed to haul it to the production site. The production site should be accessible for trucks carrying the component materials, smooth and flat if blocks are to be puddled in forms, and large enough to store materials and blocks. One-half acre is necessary for a small commercial operation.[1]

5.4 Equipment Schemes

Labor and equipment schemes will vary considerably depending on: fabrication technique, available resources, scale of production, and the efficiency desired. A description of all the various techniques and machines available would exceed the scope of this discussion. Figure 4 outlines several production techniques. In order to give the interested reader some idea of the equipment involved, Table 4 presents two simplified equipments schemes, distilled from the Center's experience and particularly applicable to caliche mixes. Considering the methods of block fabrication, the best overall results are achieved using the puddling technique. It is simple, fast, relatively inexpensive, and produces good quality blocks. The two models incorporate the puddling technique on a small scale, amenable to the owner-builder and on an intermediate scale, more applicable to

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1 Methods Manufacturing, personal communication.

a contractor, commercial venture or a community collective. Real life situations generally incorporate equipment components of both models.

TABLE 4

Activity	Small Scale	Intermediate Scale
Sifting	wood framed, hardware cloth	mechanized sifter - vibrating screen, rotating drum, etc.
Crushing	water-filled tank with handle	crushing machine - pug mill, etc.
Mixing	9-12 cu. ft. mortar mixer or concrete mixer	1 cu.yd. self-loading concrete mixer
Hauling	shovels and wheelbarrows	shovel tractor or front end loader
Molding	gang mold, hand released	mobile block machine with hopper, mold, release lever
Block Handling	by hand, wheelbarrow, dolly	forklift
Storage		pallets
Transportation	pickup and/or trailor	flatbed truck
Labor	minimum 2 people	minimum 4 people
Rate of Production	approx. 500 adobe size block per day	1000-1500 adobe size block per day

References:

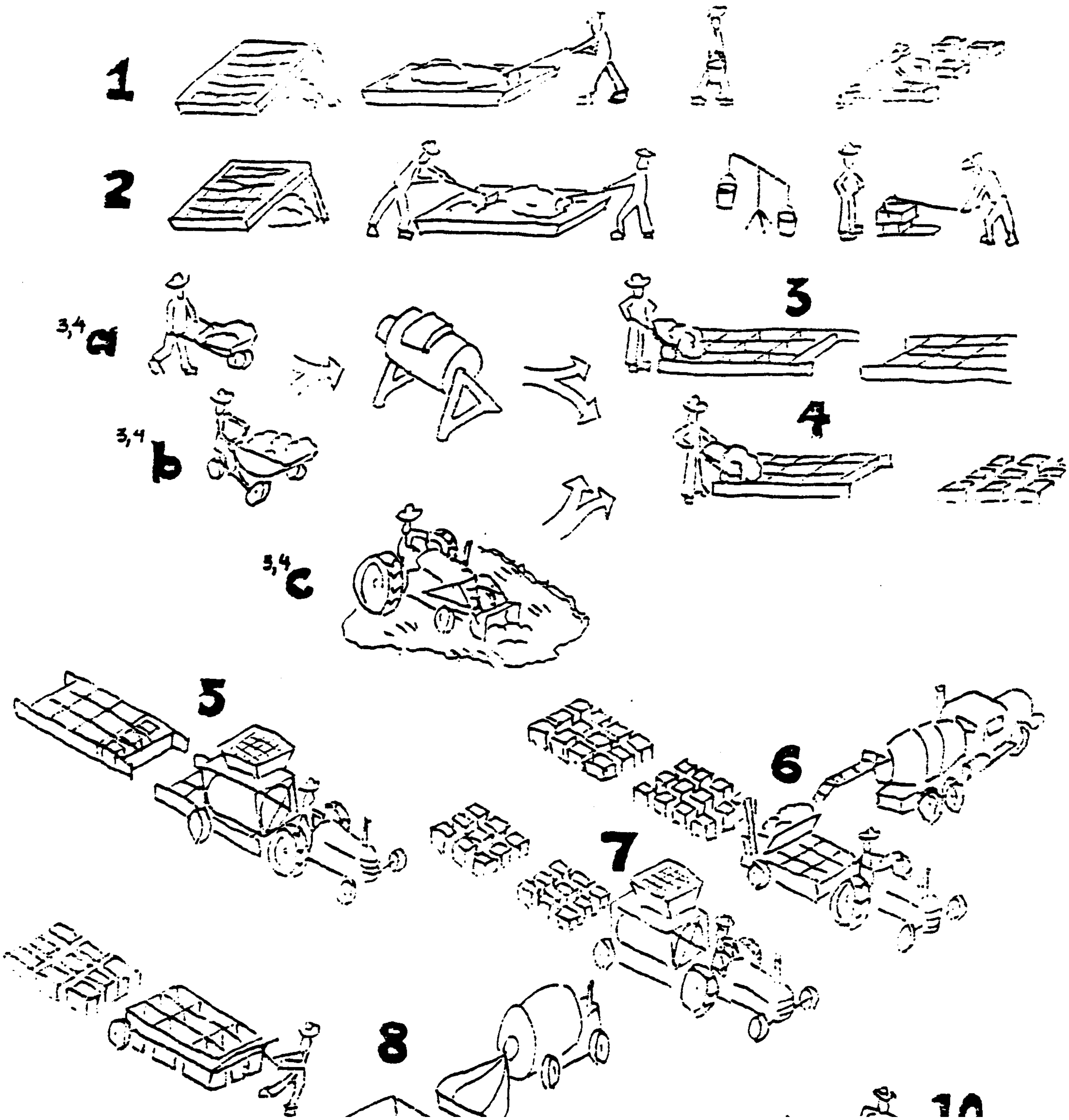
Shoemaker, et al, 1973
Musick, 1978, unpublished
CMPBS, 1978, unpublished

Figure 4

Equipment Schemes for Block Fabrication

1) Simple 2-form puddle mold
2) Hand pressed block - CINVA-Ram Landcrete, Ellison
3) Gang Mold, hand release, slow set
4) Gang Mold hand release quickset
    a) hand tools - mixer operation
    b) motorized wheelbarrow - mixer operation
    c) tractor shovel - mixer operation
5) Mixer over Gang Mold, slow set, hand release
6) Ready mix, mobile mold with hopper and lever release, quick set
7) Mixer over gang mold, quick set, hand release
8) separate mixer, hopper, wheeled mold with lever release, quick set
9) Automatic pressed block - Hi Sibley
10) Automatic pressed block - Winget

Source: CMPBS, 1978


1
2
3,4 a
3,4 b
3,4 c
3
4
5
6
7
8
10

VI. RESOURCES

For those interested in caliche building systems, this section lists some of the available resources. The resources are divided into four groups. Table 5 lists certain institutions and groups which serve as general sources of information in any particular county or region. Table 6 lists publications, which refer specifically to some aspect of caliche building systems. Table 7 is a partial list of block making machines, including price and address if available. Finally, Plate 2 contains a Point Resource Map for the state of Texas. This map points out groups that provide services related to some aspect of caliche building systems, information sources, mining operations (active as of 1974), caliche suppliers, and sites of caliche-built structures. The points are numbered and cited in the map explanation following Plate 2 with additional information and addresses where available. One last reminder, interested persons should make inquiries in their area, as other resources may be found that are not mentioned here.

TABLE 5

General Sources of Information

District Highway Engineer	Pipeline Contractors
County Road Commissioner	Earth Moving Contractors
County Agricultural Agents	Field Workers for Utilities
County Soil Maps	

TABLE 6

SELECTED BIBLIOGRAPHY

Agency for International Development
Department of Housing and Urban Development

Handbook for Building Homes of Earth

by L.A. Wolfskill, W.A. Dunlop, and R.M. Callaway. 159 p. PB 179327, Available from the National Technical Information Service, 5285 Port Royal Rd., Springfield, Virginia 22151

United Nations - Department of Economic and Social Affairs

Soil Cement: Its Use in Building, 1964, 114 p., Available from the United Nations Publications, Sales # E.64.IV. 6 ST/50A/54 N.Y.

Center for Maximum Potential Building Systems

The Soil-Test Mini-Lab, 1976, by Howard Scoggins, 21 p. CMPBS, 8604 Webberville Rd., Austin, Texas 78724.

An Appropriate Technology Working Atlas for Texas, 1977 edited by Bruce Phillips. CMPBS

Bureau of Economic Geology, University of Texas at Austin
University Station Box X
Austin, Texas 78712

Land Resources of Texas by R.S. Kier, L.E. Garner & L.F. Brown, Land Resource Lab Series #2, 42 p., 1977.

Mineral Industry of Texas, 1974: by M.E. Hawkins and R.M. Girard, Mineral Resource Circular #59; 37 pp, 1977.

Kern, Ken. The Owner Built Home

Charles Scribner's Sons, N.Y., 1975.

TABLE 7

BLOCK MACHINES

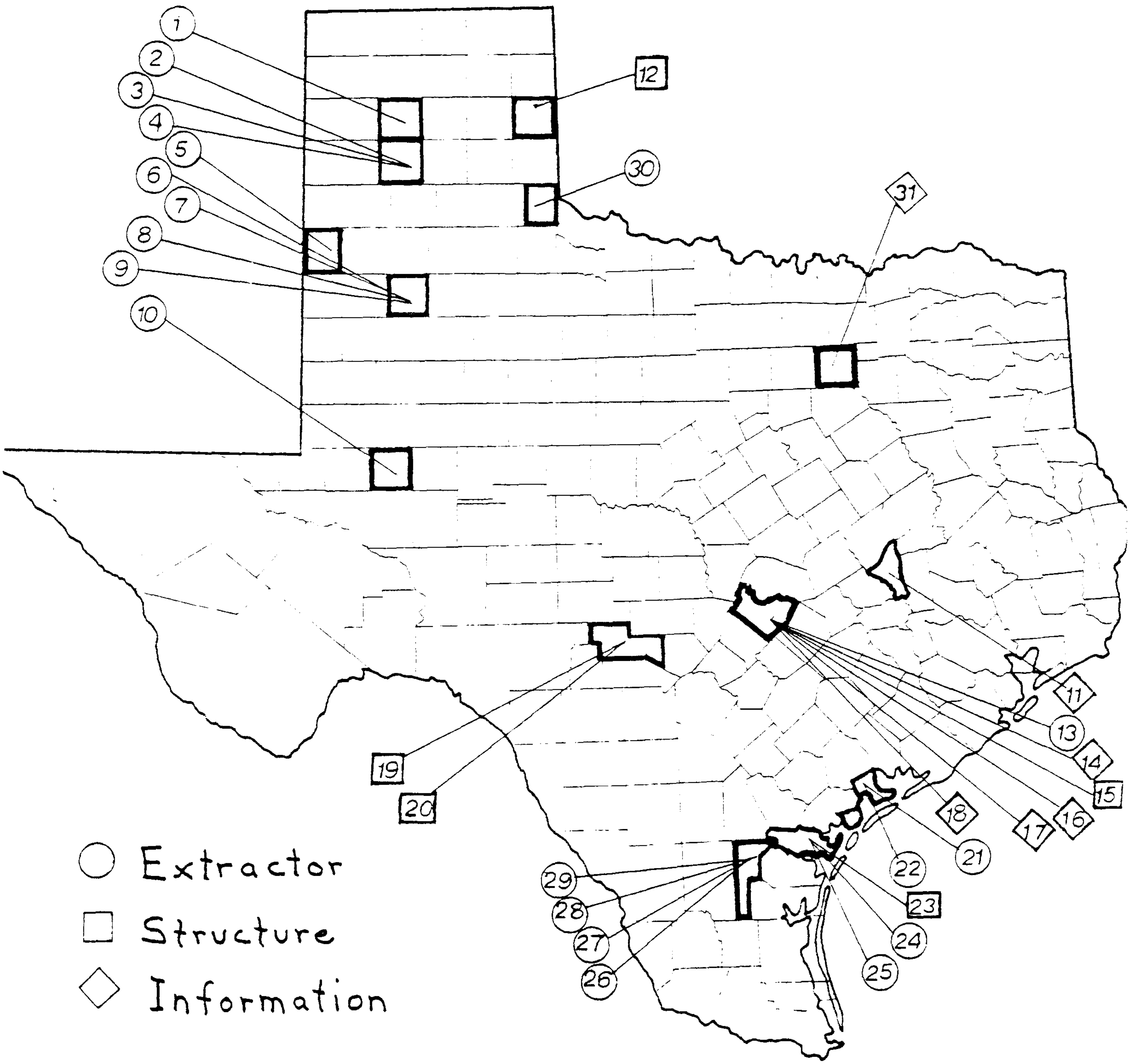
PRESSED BLOCK	SOURCE
Cinva-Ram Block Press All Steel - 128 lb. block sizes 4"x6"x12" hand operated 300/day	Metalibic Ltda. Apartado Aero 11798 Bogoto - Colombia South America -see also Last Whole Earth Catalog 1973.
Kent Machine[1] concrete block 8 x 8 x 16	Kent Co. Icuyaroga Falls, Ohio
Lancrete press[2] interlocking block various shapes hand operated	Messrs. Landsborough & Findlay Ltd. Johannesburg, S. Africa
Winget[2] hydraulic rotary machine	Winget, Ltd. Rochester, England
Ellson Blockmaster[2] hand operated various block sizes	Ellson Equipments Ltd. 283 Fox Street Johannesburg, S. Africa

PUDDLE BLOCK MACHINES

Hi Sibley concrete block machine 800 block/day	Plans for this machine printed in Mother Earth News May/June 1977
Moldmaster mobile - hand operated many block sizes available 1000-1500 adobe size block/day $2495	Methods Manufacturing 12363 Waterpark Rd. Austin, Texas 78759
a machine comparable to the Moldmaster, but with refinements for commercial yard use.	Earth Lab 1706 Karen Avenue Austin, Texas 78757

1 U.S. Navy, 1972

2 Wolfskill et.al.



POINT RESOURCES

PLATE 2

POINT RESOURCES BY NUMBER AND COUNTY

Potter County

1 J. Lee Milligan
Kretzer Pit

Randall County

2 Diel Jake
Several pits

3 Gilvin Terrill

4 J. Lee Milligan

Bailey County

5 Diel Jake

Lubbock County

6 Kerr Construction Co.

7 Lubbock Asphault Products, Inc.

8 Commercial Pavers

9 Strong Paving Co.

Midland County

10 South Texas Construction Co., Wright Caliche Pit

Brazos County

11 Texas A&M University
Engineering Experiment Station
Agricultural Experiment Station
Extension Service
Published information, Research, and Laboratory

Wheeler County

12 Several caliche structures locations unknown - check with County Agricultural Agent

Travis County

13 Texas Crushed Stone Co.
RFD 3 Georgetown, TX.

14 Center for Maximum Potential Building Systems, 8604 Webberville Rd., Austin, Texas 78724
Design & Testing, & Information

15 Pavillion - a caliche structure by the CMPBS, 6438 Bee Caves Rd., Austin, Tx.

16 The Earth Lab, 1706 Karen, Austin, Tx. 78757
Earth Construction Design and Testing, Machines available, including puddle block machine and pug mill crusher.

17 University of Texas Bureau of Economic Geology - Austin, Texas 78712 - Information and maps, land resource and mineralogic atlases.

18 University of Texas Department of Architecture Wolf Hilbertz
$CaCO_3$ precipitation in seawater for underwater structures.

Kerr County

19 Hill Country Youth Ranch Box 67, Ingram, Tx 78025
Caliche block-making and caliche structure in progress.

20 Happy Krause

Commerical caliche block
making.

Calhoun County

21 Lone Star Cement Corp.
Cement Div. - 402 Concrete
Ave., PO Box 3148, Houston,
Tx. 77001

22 Parker Bros. & Co., Inc.
5303 Navigation Blvd.
PO Box 107, Houston, Tx.
77001

San Patricio County

23 Lake Corpus Christi
State Park
Mr. A.G. Hoskins
PO Box 1167 Mathis Tx.
78368
A quarried caliche block
structure.

24 South Texas Construction Co.

25 Heldonfels Bros.
5200 Up River Rd.
PO Box 1917
Corpus Christi,
Tx. 78403

Jim Wells County

26 Oran-Joe Deal

27 Bill Wright Caliche

28 Ochoa Construction Co.

29 C.E. Boyd & Sons

Childress County

30 Gelvin Terrill

Dallas County

31 Air Craft Tooling Inc.
1623 Avenue X
Dallas, Tx. 75229
foamed earth technology

VII.

7.1 Material Cost

The cost of materials will vary considerably from one local to another. Caliche and crushed limestone will cost between $1 and $2 per ton FOB. Prices for sand will depend on its availability and its grade. Cement and quicklime vary a little in price depending on transportation costs. Pozzolan is not readily available, except in the Valley near Mission, Texas. If available it should cost no more than half the price of cement. Following is a outline of materials costs per block based on current Austin Prices, using a general puddle block formula.

Materials

Cement: $4.80/100 lb.
Quicklime: $3.00/100 lb.
Pozzolan: $2.40/100 lb.

Sand: $3.60/ ton
Caliche: $1.35/ ton
(crushed limestone)

Caliche Blocks

Dimensions: 4" x 10" x 14"
Weight: approx. 39 lb.

General Formula by weight dry		Amount of Materials for 1000 blocks
Sand	57%	11.12 tons
Caliche	35%	8.54 tons *
Stabilizer	8%	3120 lb.

	Cement Stabilized	Quicklime Stabilized	Pozzolan/Cement
SAND	$40	$40	$40
CALICHE	$12	$12	$12
CEMENT	$150	$94	$106
	$202	$146	$158
	$ .20/block	$ .146/block	$ .158/block

* assuming 20% waste from screening

7.2 Labor Cost Analysis

The following analysis is based on generalized data, obtained during the course of a recent caliche construction project [1,2]. Different equipment schemes and scales of production will greatly affect the amount and therefore the cost of the labor[3]. A cost analysis of equipment is not included in this paper, because of the many possible combinations of a variety of machines. The following presentation itemizes the block production process by individual tasks showing the approximate rate of production and the number of man hours needed to process 300 cubic yards of caliche in the production of 50,000 adobe size caliche blocks. The actual dollar and cents cost of labor can be figured by using local pay scale rates in each specific area. A comprehensive analysis of the costs of materials, labor and equipment for a large scale earth construction project undertaken in Egypt may be found in Architecture for the Poor by Hassan Fathy.

1 Musick, 1978 (unpublished)

2 See Plate 7 in Appendix B for a discussion of this caliche construction project.

3 Refer to Section 5.2 and Table 4 for additional information.

LABOR EVALUATION FOR THE PRODUCTION OF 50,000 BLOCK[1]

LABORERS	TASK	MACHINE	RATE	TIME	MANHOURS
5	excavation and trans-port	bulldozer frontend loader 3 trucks	60 cu.yd./day	5 days for 300 cu.yd.	80
1	handling materials	shovel tractor	20 cu.yd./day	80 hr.[2]	80
2	sifting	screen	15 cu.yd./day	20 days	500
2	crushing	water filled hand roller	20 cu.yd./day	3 days	48
2	mixing	mixer	-----	200 hr.	400
2	block forming	block machine wheelbarrows	250 blk/hr	200 hr.	400
3	handling and storing	forklift	1000 blk/hr	50 hr.	150

TOTAL 1,658 manhou

33.16 manhours/ 1000 block

SOURCES: Shoemaker, 1973; Musick, 1978, (unpublished)

1 Actual production will require less labor, because tasks and workers overlap and do not perform in an itemized way.

2 Half time support for the materials processing

3 Based on 20% waste after screening.

4 Includes moving the mix to the block machine in wheelbarrows.

APPENDIX A

TABLE		SOURCE
8	Worldwide Calcrete Chemistries	Goudie, 1973
9	Worldwide Calcrete Chemistries	Goudie, 1973
10	New Mexico Caliche Chemistries	Aristarain, 1970
11	Comparison of Caliche and Limestone Chemistries	Aristarain, 1970
12	Chemistry of a Carbonate Deposit - Mountain Home, Tx.	
13	Visual Inspection - Some Texas Carbonate Samples	
14	Granulometric Analyses - Four Texas Caliches	
15	Selected Soil Tests	
16	Mix Data - Caliche Block	
17	Test Results - Caliche Block	

TABLE 8

REGIONAL CALCRETE CHEMISTRY

	Sample size	Mean %	Range	Ratio of CaO	Ratio of SiO_2
North Africa					
$CaCO_3$	41	74.81	27.64-95.59	-	-
SiO_2	40	11.33	1.38-69.38	-	-
Al_2O_3	8	0.70	0.20- 1.98	-	16.19
Fe_2O_3	8	0.95	0.40- 2.78	-	11.93
Cyprus					
$CaCO_3$	16	83.62	75.00-91.00	-	-
$MgCO_3$	16	4.56	0.88- 7.14	-	-
Al_2O_3/Fe_2O_3	16	1.92	3.25- 3.06	24.31	-
CaO	16	46.68	42.50-51.40	-	-
Australia					
$CaCO_3$	38	87.97	58.36-99.40	-	-
$MgCO_3$	39	6.28	1.00-45.41	-	-
SiO_2	13	6.49	0.56-17.86	-	-
Al_2O_3	10	1.58	0.26- 3.81	-	4.11
Fe_2O_3	35	2.26	0.06- 7.10	-	2.87
India					
$CaCO_3$	12	61.02	27.07-81.00	-	-
SiO_2	25	17.92	3.19-49.09	2.24	-
Al_2O_3	12	3.13	0.04- 5.97	12.86	5.73
Fe_2O_3	12	3.62	15.97- 1.65	11.10	4.95
Al_2O_3/Fe_2O_3	9	2.70	-	14.89	-
CaO	24	40.19	15.16-51.36	-	-
MgO	25	1.66	0.00-10.30	24.20	-

TABLE 9

REGIONAL CALCRETE CHEMISTRY (continued)

	Sample size	Mean %	Range	Ratio of CaO	Ratio of SiO_2
East Africa					
SiO_2	21	14.26	0.34-45.21	2.93	-
Al_2O_3	19	2.48	-	16.85	5.75
Fe_2O_3	13	1.82	-	23.01	7.84
CaO	29	41.79	-	-	-
MgO	19	2.50	-	16.69	-
South Africa					
$CaCO_3$	82	79.13	-	-	-
SiO_2	102	11.83	3.34-46.06	3.65	-
Al_2O_3/Fe_2O_3	79	1.89	-	22.87	-
Al_2O_3	15	2.38	0.23- 7.40	18.17	4.98
Fe_2O_3	15	1.51	0.17-5.91	28.60	7.84
CaO	88	43.19	52.16-25.56	-	-
MgO	70	3.66	0.10- 8.30	11.79	-
$MgCO_3$	35	8.72	-	-	-
World Calcrete Chemistry: mean percentage					
$CaCO_3$	-	79.28	-	-	-
SiO_2	-	12.30	-	3.47	-
Al_2O_3	-	2.12	-	20.07	5.80
Fe_2O_3	-	2.03	-	21.02	6.06
MgO	-	3.05	-	13.96	-
CaO	-	42.62	-	-	-

Source: Goudie, 1973.

TABLE 10

CHEMICAL ANALYSES OF THE MAIN CONSTITUENTS OF CALICHE PROFILES FROM HIGH PLAINS, NEW MEXICO (IN WT. %)

CONSTITUENTS	PROFILE 1				PROFILE 2				PROFILE 3		
	1-1*	1-2	1-3	1-4	2-1	2-2	2-3	2-4	3-1	3-2	3-3
SiO_2	49.92	14.30	26.92	57.46	85.22	52.26	13.20	17.06	1.94	4.92	38.68
FeO	1.02	0.08	.....	.....	0.28	0.10	0.08	.....	.....	.....	0.05
Fe_2O_3	1.30	0.60	0.68	1.27	1.73	1.50	0.45	0.79	0.25	0.22	1.22
Al_2O_3	6.77	1.04	1.59	4.46	6.51	5.65	1.44	1.34	0.44	0.53	4.85
CaO	15.40	45.56	37.68	18.70	2.00	19.92	45.40	43.76	53.54	51.80	27.90
MgO	0.76	0.34	0.49	0.27	0.14	0.30	0.35	0.23	0.20	0.31	0.47
MnO	0.01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
P_2O_5	0.12	0.02	0.02	0.05	0.05	0.03	0.03	0.02	0.05	0.02	0.03
TiO_2	0.45	0.06	0.11	0.14	0.19	0.30	0.09	0.10	0.06	0.05	0.18
Na_2O	0.42	0.13	0.11	0.39	0.27	0.26	0.11	0.11	0.09	0.10	0.34
K_2O	1.15	0.13	0.23	0.57	0.79	0.78	0.22	0.25	0.15	0.16	1.03
SO_3	0.14	0.71	0.08	0.05	0.04	0.05	0.20	0.11	0.13	0.19	0.24
CO_2	12.79	35.73	29.96	14.90	1.57	15.90	36.01	34.57	41.91	40.87	22.26
H_2O-	2.50	0.26	0.39	0.34	0.28	0.61	0.40	0.27	0.17	0.11	0.41
H_2O+	3.38	1.01	1.24	1.13	1.12	1.74	1.31	1.01	0.70	0.78	1.38
Total	96.63	99.97	99.50	99.73	100.19	99.40	99.29	99.67	99.63	100.06	99.04

* Some organic matter.

TABLE 11

COMPARISON OF A COMPOSITE ANALYSIS OF LIMESTONES WITH ANALYSIS OF CALICHE SAMPLES (IN WT. %)

CONSTITUENTS	LIMESTONES (1)	CALICHE		
		Sample 1-2 (2)	Sample 2-3 (3)	Sample 3-1 (4)
SiO_2	5.19	14.30	13.20	1.94
FeO	0.54	0.08	0.08	.....
Fe_2O_3	.....	0.60	0.45	0.25
Al_2O_3	0.81	1.04	1.44	0.44
CaO	42.61	45.56	45.40	53.54
MgO	7.90	0.34	0.35	0.20
MnO	0.05	.....	.....	.....
P_2O_5	0.04	0.02	0.03	0.05
TiO_2	0.06	0.06	0.09	0.06
Na_2O	0.05	0.13	0.11	0.09
K_2O	0.33	0.13	0.22	0.15
SO_3	0.05	0.71	0.20	0.13
CO_2	41.58	35.73	36.01	41.91
H_2O-	0.21	0.26	0.40	0.17
H_2O+	0.56*	1.01	1.31	0.70
Others	0.11	.....	.....	.....
Total	100.09	99.97	99.29	99.63

SOURCES.—(1) Composite analysis of 345 limestones—H. N. Stokes, analyst, Clarke (1924); (2)–(4) from table 2.

* Includes organic matter.

TABLE 12

Chemical Analyses

Carbonate Deposit - Mountain Home, Tx.

Sample 4

Analysis 1		Analysis 2	
94.7%	$CaCO_3$	98.0%	$CaCO_3$
.2%	SO_2	.05%	Sodium Salts
		none	Sulphates
		pH -	8.0

TABLE 13

Visual Inspection

SAMPLE	DESCRIPTION
1	$CaCO_3$ consolidated in weights of 30 grams to several hundred pounds. Chaulkish white to sand color. Yellow-brown stains from iron in solution. Clay overburden in distinct lifts with little intermix of the two.
2	$CaCO_3$, clay and sand in well mixed lot. Caliche is grey-white to red-brown. Color and mix of other materials -- clay, sand -- indicate extensive leaching action of water.
3	$CaCO_3$, chaulkish white powder with sand and gravel size clumps of fine grain $CaCO_3$, easily crushed. No sand or clay present. Very little organic material present.

TABLE 14

Granulometric Analyses
of four Texas Caliches

Sample 1   CMPBS Bee Caves Site

Retained in #10 screen 40%
Retained in #60 screen 40%
Retained in #200 screen 10%
Passed #200 screen 10%

Acid Reaction:
Very Strong on #10 and #60
Weak to nil on #200

Sample 2   Travis County Site (purchased)

Retained in #10 screen 25%
Retained in #60 screen 70%
Retained in #200 screen 5%
Passed #200 screen ....nil

Acid Reaction:
Medium Strong on #10 and #60
Very Weak on #200

Sample 3   Onion Creek Pit -- Travis County

Retained in #10 screen 40%
Retained in #60 screen 40%
Retained in #200 screen 16%
Passed #200 screen 4%

Acid Reaction:
Medium on #60 and #200

Sample 4   Priour Ranch -- Mountain Home, Tx.

Retained in #10 screen 35%
Retained in #60 screen 60%
Retained in #200 screen 5%
Passed #200 screen ....nil

Acid Reaction:
Very Strong on all screens

TABLE 15

Selected Soil Tests
on Texas Caliche Samples

Sample	Liquid Limit Reaction
1	Medium Liquid -- Slow Liquid Reaction
2	High Liquid -- Fast Liquid Reaction
4	Medium Liquid -- Slow Reaction
	Alcock Box Measurement
1	Average Contraction of 3 samples 3/4" Stabilizer Ratio - 1 part cement to 16 parts soil
2	Average Contraction of 3 samples 1-1/2" Stabilizer Ratio - 1 part cement to 14 parts soil
3	One Sample Contraction 3/4" Stabilizer Ratio - 1:16
4	One Sample Contraction 1" Stabilizer Ratio -- 1:16
	Siphon Test
1	30 minute Brownian Movement separation of silt from colloids by weight -- .05 grams
2	Separation of silt from colloids by weight -- 1.2 grams.

Note: Sample 1 has high carbonate content (83%) and low colloid content.

Sample 2 has high clay and sand content and a greater colloid content.

TABLE 16

Mix Data
(by per cent weight wet mix)

Pressed Block -- Cinva - Ram

Sample	Caliche	Sand	Cement	Water
B0R	65	20	8	7
B1R	38	38	15	10
B10R	26	52	9	13
B11R	40	40	12	8
B12R	35	45	10	10

Note: Sample 1 caliche used for Pressed Block Formulas

Poured Block - sample 4 caliche

LP	30	50	Lime 5	15
G	17	55	Lime 13	15
PZ[1]	31	46	PZ/Cem 8	15
PC2	36	40	Cem 9	15
PC3	36	42	Cem 7	15
PC4[1]	31	47	Cem 7	15
PC5[2]	31	47	Cem 7	15

1 mixes with best results

2 chat substituted for silica sand
(crushed limestone)

TABLE 17

TEST DATA

Pressed Block - Cinva-Ram

Program I

Sample	Low/High - Compression Strength in psi
B10, B11R and other samples of which mix data is not available	1150/1360 Average Value

Program II

B0R 600/670

B1R 878/975

B10R 716/950

B11R 703/1127

B12R 765/980

Total number of blocks tested in this series - 41

Poured Block

Program III [1]

Sample	Compression Strength in psi	Average Strength	Average Absorption % dry weight
LP	366,241,418,345	343	----
G	166,288,200,230,251	227	----
PZ1	306,281,277	288	----

Program IV [1]

Sample	Compression Strength in psi	Average Strength	Average Absorption % dry weight
LP	------	---	13.6
PZ1	518,487,493,466,510, 485,472,522,490,488	493	9.8

Table 17 continued

Program V

Sample	Compression Strength in psi	Average Strength	Average Absorption % dry weight
PC1	215,223	219	15.93
PC2	851,804	828	15.26
PC3	578,557,565	567	17.26
Program VI [1,2]			
PC4	835,840,980,930,1157	948	15.66
PC5	840,553,603	665	17.7

1 Compression tests performed on samples at 8% moisture content.

2 Samples were part of quality control program in the field and do not meet lab standards for mixing procedure.

APPENDIX B - Information Resources

Plate 3	Earth Building Materials Research at Max's Pot -Texas Adobe News
Plate 4	Adobe Comes to Austin
Plate 5	Calcium Carbonate Resources in Texas by Counties, including production 1943 -Bureau of Economic Geology
Plate 6	Commercial Caliche Extraction -Heldenfels Brothers
Plate 7	The Ingram Experience Caliche Construction Project
Plate 8	The Pavillion Experience A Caliche Design Experiment
Plate 9	Photographs of Rammed Caliche Construction and Quarried Caliche Building
Plate 10	Photographs of the Soil-Test Mini-Lab and Caliche Block

Earth Building Materials Research At Max's Pot

by
Howard Scoggins

The Center for Maximum Potential Building Systems, known to its friends as Max's Pot, is a not-for-profit Texas corporation located in the hill country near Austin, Texas. We are a group of architects, engineers, soil-testing specialists, etc., whose design perimeter is regional, based on the semi-arid and hot-arid Southwestern United States. To date we have developed prototype systems for bio-gas units, wind generators, active and passive solar systems, greenhouses, earth heat and cooling systems, solar stills, waste recycling, and building materials. These systems are designed to integrate life-support systems with energy and environment conservation, and are available for purchase at a very low cost to interested readers.

Philosophically, we are Appropriate Technologists, working holistically to integrate technology with environment preservation. Our bias is for those people favoring self reliance and self sustenance. Although our systems can be used commercially, their main thrust is for the Owner/Builder, to serve as useful tools in his successful contention with some of the basic problems of living.

My work at Max's Pot is with the development of earth building materials. Building with earth is of great antiquity, but there is little knowledge or skill left in the world today. For example, I wanted to know exactly why some soils can be stabilized for building use while others cannot, but my question found few answers in the current literature of highway and foundation specialists. To answer the question I designed and assembled the portable "Mini Soil-Testing Lab."

The Mini Soil-Testing Lab

The Mini Soil-Testing Lab consists of a manual of testing procedures and a portable tool kit. With it can be answered: 1) the granulometric curve of the soil sample (particle size and percentage); 2) the plastic index (limits of shrinkage or expansion) and corresponding ratio of stabilizer to size the soil for use; and 3) the percentage of soluble colloids (the active element of shrinkage and contraction) in the soil. We use this Lab to spot suitable soils and mineral ores for building use either in the field or at the building site. This means substantial savings in time and money because we no longer have to fabricate test blocks and wait for the results. The Mini-Lab was funded by an agency working on the Sub-Sahara Project in Africa, videotaped with Portuguese and French sound tracks and hopefully will lead to further development of the Lab possibilities.

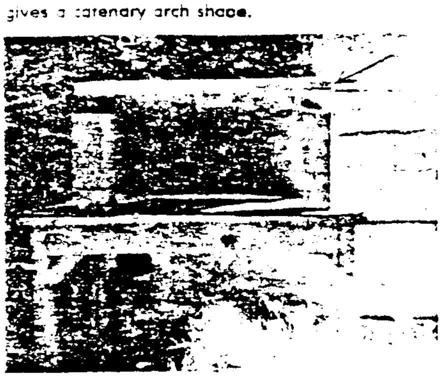
Another problem I face is gathering precise data on the stress reactions of earth building materials. Such questions as compressive strength, moisture resistance, weathering and internal responses to alternating heat and cold are critical, especially when building with earth materials in regions where there is little or no earth building expertise. These questions are also critical for those who must meet engineering requirements and codes. Unfortunately, such tests are not easily done without costly equipment or expensive testing. To meet this need I designed a second test unit called the "Maxi Lab." This unit has not yet reached the prototype stage because we haven't found funding for it. That's a hint — whoever and wherever you may be.. This Lab can be set up in a space 8'x12' on a flat-bed truck, garage, etc. to perform compressive tests up to 80,000 lbs., gauge moisture absorption, abrasion and freeze-thaw cycles, and so forth, for a plant cost 1/20th that of commercial units. It is assembled from on-the-shelf items from local junkyards, used appliance dealers, etc. It's more costly to assemble than the Mini-Lab, but ought to be well worth the price for small contractors, schools and co-op builders.

A third project underway pertains to the use of caliche as a building material. Central Texas has very little sandy-clay loam from which to make adobe. There is a great deal of caliche. I found some evidence that caliche has been used as a building material, but tests here at Max's Pot suggest that caliche has great potential.

Caliche block wall mock up

This wall mock-up shows caliche blocks of various shapes in a double-wall. These blocks were fabricated in a Cinva-Ram, and have consistently tested 1250-1300 psi, stronger than masonry blocks. Moisture tests on a 24 hr submerged block show absorption limits to be about 3%, resistance to surface abrasion is very good, and freeze-thaw tests have had no effect on test samples after 15 continuous cycles. The cost of materials for a 5½x4x11½" caliche block is $.02, compared to a single brick at $.20. Caliche blocks can be colored by adding alkali-resistant pigments and can also be made with a thick plaster face, combining both fabrication and plastering in one labor-saving operation.

Next spring, in an off-shoot of the caliche project, I will be casting beams, columns, window-sills, slabs and tilt-up panels. This new process, called "KEMCRETE"© is based upon chemical additives to the basic caliche formula. No pressure will be used to form the material, allowing any shape the mold may impart. The photo below shows a roof-tile formed in a "sag mold" which gives a catenary arch shape.



Two foot by two foot caliche roof tile

Readers may be interested in these Kemcrete blocks cast in adobe molds. Weighing about 30% of similarly sized adobe blocks, the Kemcrete blocks have tested out to 380-425 psi. We expect the psi limits to go up without increase in weight to 450-500 psi after improvement in formulation of Kemcrete.

Finally, a few words about the thermal properties of earth materials. The No. 11 Adobe News issue had an excellent article by Dr. H. Allan Fine

"Adobe formed," puddled caliche block

on this subject. Thermal diffusivity (thermal flux) is the principal process wherein the building fabric of an earthen structure develops a time-lag: a measurable period of time before the thermal capacity of the wall is reached and heat begins to "flow" from the hotter to the cooler side. Density of the building fabric plays an important role in this process. Density can be engineered by other means than the total thickness of a wall. For instance, by compression of earth into blocks, forms, etc., greater or lesser weights of material can be made to occupy the same space. In certain cases, density can be increased without lowering resistance to heat flow, depending upon the properties of a specific material.

I am now constructing a portable testing apparatus that can do this analysis, testing the thermal state in which such activity occurs. I call this process "thermal tailoring," and with it, we can design precise volume controls into the fabric of the structure. "Passive systems" are after all anything but passive and we need to know much more about the process.

Max's Pot has submitted a proposal entitled "EARTH-LAB"© to several private and public foundations for funding. EARTH-LAB would conduct a major study of earth building materials in the four climatic regions of Texas. Samples will be processed through a Mini-Maxi Lab of low cost and high precision. Engineering data will be correlated with climate data and design perimeters for structures suited to the specific region developed. All data will be published in loose-leaf form under the title "Earth Building Materials Atlas for Texas."

Max's Pot is interested in conducting studies of and soliciting funds from the entire Southwestern United States. Interested parties are invited to write us for Max's Introductory Brochure.

To: Maximum Potential Building Systems
6438 Bee Caves Road
Austin, Texas 78746

Below: Earth heat exchanger tubes
—Burlap "cement-starch"

How to Make Caliche Bricks

ADOBE COMES TO AUSTIN

by Michael Eakin

Standing amidst the scruffy cedars and raffish wildflowers at Max's Pot in Oak Hill, inventor-jack-of-all-trades Howard Scoggins is percolating happily along in his work, sifting the sandy loam, testing caliche, smiling to himself. For Scoggins is at home in his element, caliche soil. And why not? For Howard is a self-described "dirt freak," a "soil mechanic," an inventor-adaptor bent on teaching Texans to build with the cheapest material around. Dirt.

Dirt? That's right. *Terra firma*. At Max's Pot, Austin's ragtag collection of solar aficionados and utopian engineers, Scoggins is stating his case:

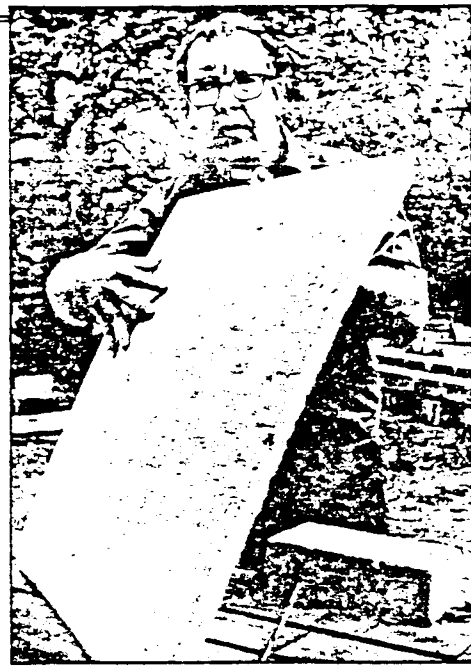
"Around these parts when most people think of a house, they think of a lumberyard. In Central Texas that's backwards thinking—totally—because we're in an area low on timber. Consequently lumber is not dirt cheap—pardon the pun. A much more sensible approach is to use what you have."

"Myself, I'm a dirt freak. There it is right in your back yard, tons of it, just begging to be used. We Americans are so over-technologized we've forgotten the most popular building material known through the millenia. Dirt's cheap, fireproof, is the best insulator around, and it's incredibly easy to work with. In short, soil-cement building techniques are the best answer to our housing shortage. Folks get the satisfaction of building their own homes and best of all, they won't owe the bank for thirty years."

As a "soil mechanic" or scientist of the soil, Scoggins spends a good part of his time developing data which proves that soil-building techniques are cheapest, the best insulators, *et al.* And finally, after two years of concentrated applied research at Austin's Center for Maximum Potential Building Systems (Max's Pot), Scoggins has gained international recognition as one of the handful of true innovators in the field. In October, Scoggins narrated a one-hour how-to film for use by the United Nations, a film now in use in four languages. Then, in December, 1976, the University of California at Berkeley asked Scoggins to conduct a workshop seminar there on adobe construction; the World Church Service will be using Scoggins' techniques in the construction of a 300-unit village in Zaire; and *Adobe News*, the popular magazine in the field, printed the first of a series of articles by Scoggins detailing his research methods. As the public slowly rediscovers soil as a building material, Scoggins' work is claiming the attention it deserves.

Why Use Soil Cement?

As Scoggins will be the first to tell you, the interest is aroused primarily because people are just now finding out how incredibly *cheap* building with soil really is. He jokes about "sweat equity replacing capital." By using a Cinva Ram (brick compressor), Scoggins has been turning out soil-cement bricks at the rate of about two to three cents a brick. Depending on the type of soil available on-site, adobe-clay, caliche-brick, and soil-cement blocks may be produced by mere compression (no glazing or heating process). Using your own labor and some elementary bonding materials (cement is the most common), Scoggins estimates that one owner-builder can create the materials for a 1,000-square-foot house for less than $300. The basic building material, caliche, is available just about everywhere in Central Texas. But there are other, equally good reasons to build with soil-cement.



Six cents is what it cost to make this soil-cement roof tile.

• *Insulation.* As Scoggins and other researchers at Max's Pot are documenting, soil-cement structures, stabilized correctly with cement or lime, beat every other building material in the creation of a "passive" environment. That means that cool air tends to stay in the house during summer, and warm air in winter. And that means very low gas bills.

• *Fire resistance.* In one of Scoggins' newest techniques, 2x4 lumber studs are unnecessary for vertical support. Obviously, by cutting the use of wood to a minimum, you minimize the danger of fire. In a soil-cement house, there is nothing in the walls, floor or roof structure to burn.

• *Attractiveness.* Because caliche is an intermediate form of limestone, it should come as little surprise that the finished caliche blocks resemble nothing so much as . . . limestone! Depending on the amount of caliche in the brick mixture, coloration ranges from an earth-like light brown to a stone-like whitish-pink.

• *Strength and durability.* Last fall Scoggins tested the strength of his caliche blocks at UT's Civil Engineering Laboratory. The results were enough to stun University engineers in attendance: all the bricks tested out with at least twice the strength of conventional, store-bought masonry blocks. Scoggins' best caliche-mixture bricks tested out in excess of 1,300 pounds per square inch of pressure, more than three times stronger than commercial cinder block.

Scoggins estimates that one owner-builder can create the materials for a 1,000-square-foot house for less than $300.

• *Resource conservation.* By building their homes mostly with wood (a scarce resource) and commercially made brick (an energy-consuming process), Americans are using up resources that are ever more costly and scarce. By building wisely you use what you have, and in semi-arid Texas that's primarily caliche.

• *Simplicity of technique.* Unlike most of today's building technologies, soil-cement construction can be learned by just about anyone (laying the 12x4x6" blocks is very similar to laying masonry block). Thus elbow grease counts more than skill. Scoggins estimates that three people could produce enough brick in about 15 days for a 1,000-square-foot structure. The labor is intensive, of course, but the finished product is *yours*, without 30 years of interest payments at Austin National.

Help Is on the Way

So just how does one go about learning the fine points of building a soil-cement home? Up until now, the owner-builder pretty much had to experiment around, learning what he could from Ken Kern's excellent *The Owner Built Home*, among other related books. By fall, however, Scoggins plans to publish an *Earth Building Manual* covering in detail the fine points of building with soil-cement mixtures, and focusing especially on caliche.

Already, Scoggins has developed a portable tool kit called the "Soil-Test Mini-Lab" with which anyone "with basic reading skills and a modicum of patience can extract, analyze, and classify soil samples to determine the most suitable building process." Also, he conceptualizes a low-cost, portable Maxi-Lab "which would enable the owner-builder to determine *on-site* such sophisticated measurements as analysis of weathering characteristics, structural and thermal variables, etc." With the publication of the *Earth Building Manual* and creation of the Maxi and Mini labs, even the rankest amateurs will be able to build quality control into their own structures.

Among the folks at Max's Pot, though, the concept of quality control goes beyond the utilization of any one building technique. At the Pot, the emphasis is on both cost *and* creative design techniques. Give Scoggins a nudge in the right direction and he'll talk about the goal of "passive structures."

"Ideally, what we're after is to design a living structure as an atmosphere engine. In the past we've always seen a dichotomy between reasonable cost and aesthetics—you had to choose one or the other. We've found that by combining the owner-built concept with an intelligent design concept we can cut the energy needs of a structure by 80 percent or thereabouts. What we're after is dynamic as opposed to static structures—buildings that respond to different seasons, light, heat, and wind patterns. This enables us to create various hot spots, cold spots.

cont. on page 20

Howard Scoggins, dirt freak, examines caliche bricks made at Max's Pot in Oak Hill.

Aids for the Soil-Cement Builder

If you're interested in building with soil, there are several excellent books and articles on the subject, in addition to local access to the refined techniques of soil-mechanic Howard Scoggins. First, however, the budding owner-builder needs to research the wonders of the Cinva ram, an amazing tool which should enable you to produce better, stronger blocks than anything on the market.

A few words on the Cinva ram: this little box-and-lever tool was invented in the mid-1950s by a Chilean engineer named Paul Ramirez. The patent was subsequently acquired by the Rockefeller interests, and is available today for about $275 from Bellows International Company, 200 W. Exchange St., Akron, Ohio 44309. The ram itself is an ingeniously simple metallic box-mold which can be filled with damp, soil-cement mixture, then compressed by a long lever-like piston which exerts 40,000 pounds of pressure on the mixture. The brick formed by the compressive action is then ejected to be set in a cool place and left to cure for up to three weeks.

The actual brick-making process itself is labor-intensive—it costs almost nothing, but requires hours of your own effort. Construction using the Cinva ram involves about five steps: (1) analysis of the soil, (2) sifting of the earth, (3) preparation of the mix, (4) manufacture of the blocks, and (5) curing of the bricks. For more detail, you'll want to consult the following books or articles:

• The May, 1976 issue of **Mother Earth Magazine**, which contains an excellent introductory article by C.D. Folsom.

• **The Handbook for Building Homes of Earth**, by L. Wolfskill, W. Dunlop, and B. Callaway, available for $8.25 from the National Technical Information Service, 5825 Port Royal Road, Springfield, Virginia 22161

• Chapter 18 of Ken Kern's The Owner-Built Home, available at local bookstores for $7.50 in a quality paperback.

• **Cinva Ram Book**, VITA, College Park, Maryland, $1.50.

• **The Mini-Lab Soil Manual** by Howard Scoggins, $4.00, 2nd ed. available in March 1977

~~[illegible]~~

Soil Cement

cont. from page 3

and medium-temperature areas within the structure—the home is a series of transition zones. By gradually adjusting room temperature, the body is rid of its need for a high-cost constant temperature.

"Just about anyone with standard carpentry skills can do these things now—using thermal chimneys, temperature-time-lag walls, Trombe walls, earth-air heat exchangers—all of which about equal the initial investment most people make in plumbing and temperature-control systems. The difference is, even low-income people can afford these innovations *along with* solar and wind energy, *if* they build cheaply, using what they have."

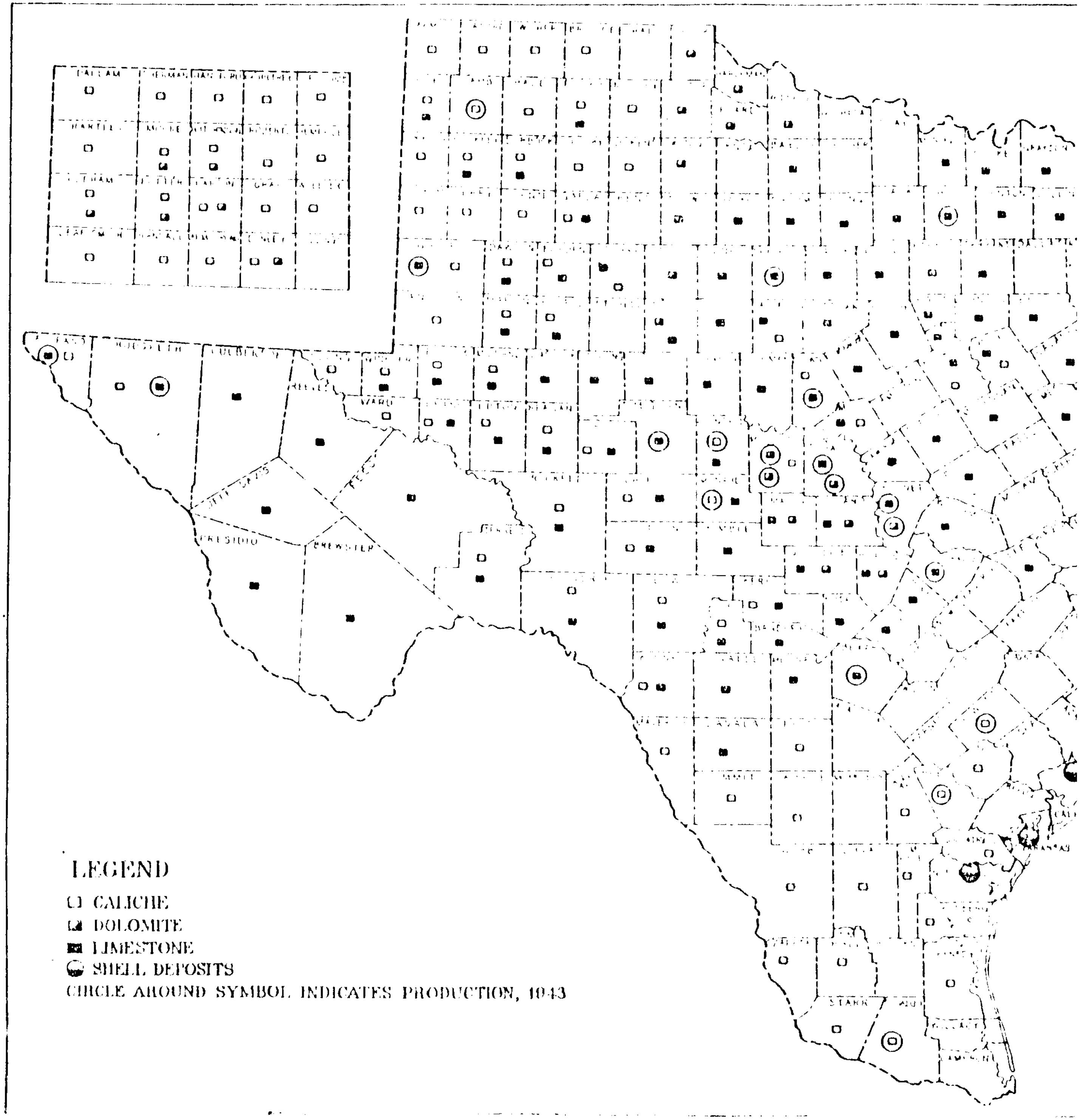
If Dirt Was Trumps

As with his colleagues at Max's Pot, Scoggins took the long way around in coming to his current advocacy of a more self-reliant, decentralized society. In the early 70s he surveyed the checkerboard, colorful history of his adult life,—"there I was approaching my forties, burnt out"—and decided on a basic change in direction. Vitally affected by the environmental movement and books like *The Owner Built Home*, Scoggins began to see implications for fundamental reform behind the simple notion of self reliance—"of free men and women who cannot be bought off by the Corporation or State because they can provide for their own needs full well." In the spring of 1970, he left town for Houston to learn the bricklaying trade. For three years he apprenticed himself to master bricklayers, then formed his own subcontracting firm. His experience in building custom homes in the $70,000 to $80,000 range convinced him that traditional building techniques were "just another form of involuntary servitude in an over-technologized, wasteful society. In '7[illegible] he left Texas for California, where he worked for two years with several other theorists, such as Ken Kern and the Whole Earth Catalog people, doing basic research on low-cost methods of

Using caliche-mixture bricks, the labor is intensive, but the finished product is yours, without 30 years of interest payments at Austin National.

construction. Then, in 1975 he returned to Austin with his wife Donna and children Mitchell and Maria to perfect his techniques. In January, Scoggins was elected a project manager at Max's Pot, giving him the opportunity to further develop his ideas.

What lies in the future for Howard Scoggins and his use-what-you-have technology? Scoggins himself is optimistic, and fond of quoting the Englishman Charles Lamb on the subject: "Martin, [illegible] dirt was trumps, what hands you'd hold!" Scoggins' message is that the old terra firma is trumps, and that we, and he, hold a very good hand. •


PRESIDIO
BREWSTER
STARR
LEGEND
CALICHE
DOLOMITE
LIMESTONE
SHELL DEPOSITS
CIRCLE AROUND SYMBOL INDICATES PRODUCTION, 1943

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HOT MIX ASPHALT
CALICHE

P. O. BOX 4957
CORPUS CHRISTI, TEXAS 78408

December 1, 1976

Mr. Steven P. Musick
5700 Cameron Rd. #220
Austin, Texas 78753

Dear Sir:

Caliche lies as a rule, near or on the surface in South Texas. We usually locate it first from an outcrop or from information supplied by a landowner, a pipeline contractor or some other person who might come across caliche in the field. In other words by the scientific method of word of mouth.

Once a source is located, we send a drill to determine the depth and area of a deposit. If the source looks promising both from the stand point of size and quality, the next step is to drill and shoot a small area. This material can be loaded and hauled to a crusher or a small amount can be crushed in the laboratory. A detailed lab report is obtained as to hardness, gradation, plasticity, etc.

At this point we have a fair idea of the equipment needed to produce this material as well as what the material is suitable for in the way of construction.

Most caliche is produced with a mobile plant for two reasons. First, deposits are usually not large enough for a permanent plant. Second, deposits are numerous enough to move around and locate as near as possible to the location the caliche is needed, therefore, cutting the haul cost which has climbed along with the price of fuel.

The processing operation starts with clearing any brush and stripping any topsoil off the deposit. This varies, but seldom amounts to much more than light brush and up to 2 feet of stripping.

The actual processing involves loading and hauling to the Crusher, the actual crushing and screening operation and the stockpiling operation.

Loading and hauling is in most cases done with a large rubber tired HiLift in the 6 to 7 cubic yard class and hauling is usually done with off road rear dump trucks in the 20 to 30 ton class. It should also be said that most deposits are drilled and shot with explosives to facilitate loading, but not always. One HiLift and three haul units would

Page 2 December 1, 1976
Mr. Steven P. Musick

normally be enough to supply between 2000 cubic yards and 5000 cubic yards to the crusher in a 10 hour day depending on the deposit and the haul. One rotary drill would probably keep up with the drilling in most deposits.

Crushing and screening operations vary considerably. Most operations include a large Feeder which feeds either a combination crusher or a primary crusher with a screening unit to bypass the finer material. If a combination crusher such as a double rotary impact is used, the material then goes to a screening unit which returns any material not small enough back to the same crusher and sends the rest along with that material already bypassing the crusher from the first screening unit to a hopper as finished product. If a primary crusher is used, then the process includes another crusher called a secondary crusher. These might be a Jaw and a roll or triple roll crusher. In this case the Feeder feeds the Jaw. The material crushed by the Jaw goes to the screening unit where the oversize goes to the secondary crusher for further sizing and back to the screen. The finished material again goes from the screen to a hopper. There are numerous other combinations, types and sizes of crushers, but most include the components mentioned and most produce between 2000 to 5000 cubic yards in a 10 hour day. Power is usually a combination of diesel and diesel electric.

The material is dropped from the hopper into 20 to 30 cubic yard rubber tired scrappers and stockpiled in 1 to 2 foot lifts. The pile might end up between 15 to 25 feet high having as much as 150,000 cubic yards of caliche.

Stockpiling is done in this way because of the inconsistency of caliche even within the same deposit. It is stockpiled in layers to blend the different types of caliche within the same area. The stockpile is loaded out by a HiLift reaching up the face and thus getting a well blended material. If interim tests are kept on the layers, the quality of the blended material can be controlled by loading the crusher from different parts of the pit.

Costs vary as much as equipment and deposits but a general rule would be one dollar a loose yard in the stockpile. The cost of loading and hauling would have to be added to the cost in the stockpile to get a delivered price.

This is a very general outline of how caliche is found and produced in South Texas by Highway contractors and large commercial producers. There are other methods and details of the operation not explained in this letter. I would be glad to answer any questions you have and even show you some pits and operations if you are around Corpus Christi sometime soon.

Sincerely,

John O. Heldenfels

JOH/vt

THE INGRAM EXPERIENCE

In the Spring of 1978 the Center began work on a project[1] which will result in a passively designed caliche schoolhouse for the Hill Country Youth Ranch in Ingram, Texas. A locally available carbonate deposit was found and tested for its building qualities. Various stabilizers and mix variations were tried and tested. And a formula was developed using cement as the stabilizer, because of its excellent building properties and local availability. The Hill Country Youth Ranch set up for block production[2] by purchasing a Moldmaster Block Machine, a 1 cubic yard concrete mixer, a shovel tractor, and acquiring the use of a large warehouse for the production area, because of its ideal surface conditions and protection from winter weather. The caliche was excavated by bulldozer and payloader, and hauled to the production site in large trucks by a local contractor. Approximately 300 cubic yards of caliche was transported to the production site in five days. A coarse grained sand was purchased from a supplier in the area. Four to six laborers were employed in handling the materials, mixing the components, and forming and storing the block.

The caliche was dried and screened at the rate of about 10-15 cubic yards per day, using the shovel tractor and a 4' x 6' frame covered with $\frac{1}{4}$ " hardware cloth. Two to four workers were employed in this phase of the production. The production rate for mixing the components and forming the blocks was 1200 adobe size (4"x10"x14") blocks per day. Production was less than expected because of the limited space in the warehouse. Total production was 15,000 block over a span of two months. The cost per block was figured at $ .22, including labor, materials, and transportation. However, due to the charitable nature of the project, there were many donations of material and labor.

Problems were encountered which reduced the rate and efficiency of the block production. Some of the major problems included the limited amount of space for block production and block storage, delays resulting from freezing and rainy weather, initial difficulties in acquiring and maintaining equipment, effective drying and crushing of the caliche material, and the inexperience of the workers in this type of construction. None of the problems proved insurmountable. After several weeks of trial and error, the mixing crew was producing a continuous supply of caliche mix to the non stop operation of the block machine[3].

1 Musick, 1978 (unpublished)

2 See the generalized production scheme in Section ____.

3 Data from the Ingram Project is included in Appendix A.

THE PAVILLION EXPERIENCE

To date the Center has been involved in two caliche construction projects, in addition to past and current research efforts. In the Fall of 1977 a small structure was completed at the previous site of the CMPBS on Bee Caves Road in Austin Texas. The structure is known as the Pavillion, and incorporated six different wall materials, including three types of caliche construction[1]. The Pavillion integrates several "passive solar" climatic systems. The original intention of the Pavillion was the testing of various combinations of these design features, but grant funds were not continued for final research.

The three types of caliche construction employed in the Pavillion design were Rammed Caliche, Poured, and Cinva-Ram caliche block. The cost for materials was approximately the same for each caliche wall. The main differences were in the amount and type of labor involved and in the durability of the wall surfaces exposed to exterior environmental factors. After a year and a half the Poured Caliche wall showed slight pitting, and the Rammed Caliche wall showed severe pitting but no cracks[2]. The Poured Caliche wall required the least amount of work, and is the best wall when durability is balanced against ease of construction. The Cinva-Ram block required the most labor and time, especially in the brick making procedure. The Rammed Caliche wall required the most skill and a comparatively large amount of labor in the construction and handling of the slip forms.

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1 CMPBS, 1977

2 The Cinva-Ram wall was protected by exterior glazing from erosive forces. However, Cinva Ram blocks in other experiments show little or no pitting after 2-1/2 years of constant exposure outside climatic conditions.

Students work the slip form up for the next layer of rammed caliche at the Pavillion in Austin.
-see CMPBS, 1978-

Recreation building built of quarried caliche at Lake Corpus Christi State Park
-See Point Resources Section-