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# Engineering Properties of Mississippi Clays

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The Mississippi Mineral Resources Institute
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FINAL REPORT

# ENGINEERING PROPERTIES

# OF

# MISSISSIPPI CLAYS

BY

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## ABSTRACT

This report summarizes the results of a second investigation to determine the feasibility of using the Atterberg Limits test as an initial evaluation of clay deposits being considered for economic use. The first study sampled and tested clays only from Northern Mississippi. The results of that sampling and testing, when plotted on a Plasticity Chart, exhibited an apparent grouping correlation between the Atterberg Limits test data and the industrial use of the clay. However, the number of samples from clay mines were few, so the validity of the groups by use could not be confirmed. This study sampled all known active clay mines in Mississippi. The Atterberg Limits were made on the samples and the results were plotted on the Plasticity Chart. The apparent groupings by commercial use that were observed in the first study were verified by the results of this investigation. This investigation has proven the Atterberg Limits are a good test to make preliminary assessments on the potential of clay deposits for commercial use.

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# INTRODUCTION

This report summarizes the findings of a study to determine if the basic properties of clay as defined by the Atterberg Limit tests conducted on clay samples collected throughout the State of Mississippi are correlative to the commercial use of clays. All known active commercial clay mines in Mississippi were sampled and tested.

The study covered by this grant was a continuation of two previous funded investigations involving Mississippi clay resources.

## 1986-87 Project

In 1986, the author was awarded a small research grant by the Mississippi Mineral Resources Institute (MMRI) to investigate the basic engineering properties of clay deposits in northern Mississippi. The main focus of the study was to determine if the Atterberg Limits tests could be used as a first assessment when evaluating clay deposits for commercial exploitation.

The Atterberg Limits tests were selected during the 1986-87 investigation because, as a standard index test in geotechnical engineering, the tests are:

1. easy to perform
2. rapid
3. reproducible
4. inexpensive

In addition, the amount of material needed to perform a test is minimal so that core samples are adequate to use as test samples. However, the primary reason for selecting the Atterberg Limits in assessing clay deposits for possible commercial exploitation was the tests evaluate the basic plastic properties of clay and silt soils. Much data existed from previous geotechnical evaluations and research which served as a standard in evaluating the project's data.

Although the 1986-87 study was limited to clay samples collected in northern Mississippi, of which only eleven were from commercial mines, the test data exhibited distinct grouping trends when plotted on a Plasticity Chart, Figure 1. The author concluded the Atterberg Limits might be a good index test for making preliminary appraisals of clay deposits for commercial exploitation. Because the number of data points of clays mined for commercial use were only eleven and were confined to northern Mississippi, it was acknowledged the apparent correlation of the Atterberg Limits to the commercial use required more sampling and testing for verification.

1987-88 Project

A second grant was awarded the following year to test the samples collected in 1986-87 for flexibility. Flexibility is the ability of a clay, when excavated and recompacted, to differentially deform without cracking. The importance of this investigation was to see if the clay deposits of northern Mississippi were pliable (putty-like) enough to be source material for compacted clay liners used as permeability barriers in hazardous waste sites, landfills, lagoons, mining refuse disposal, and levees.

The results of the 1987-88 flexibility study were inconclusive when correlated to the Atterberg Limit data of the previous year. In the author's opinion, the erratic nature of the test data was due primarily to poor testing procedures. The tests were done as special projects by different students to give them experience in laboratory testing and research.

The 1986-87 and 1987-88 investigations provided the foundation for this study. For more information and details of the two previous studies, the reader is referred to the final reports listed in the references.

## PROJECT FOCUS

The project summarized in this report focused on verifying the apparent groupings/ trends between the Atterberg Limits data of the 1986-87 project and the commercial use of clay when plotted on the Plasticity Chart, Figure 1. To accomplish this objective, the investigation limited the new sample collection to commercial clay pits and expanded the sample area to the whole State of Mississippi. The Atterberg Limits again were designated as the primary laboratory test to be made on the samples. Several simple in situ tests were to be tried at the collection sites for possible additional correlations to the Atterberg Limits and commercial use.

## SAMPLE COLLECTION

Samples tested in the 1986-87 study were collected mostly from the northern third of the State of Mississippi. About half of the samples were from active clay mines. The remaining samples were from unmined outcrops.

Prior to the field sampling program, Mr. William A. Gilliland, Head of the Mining and Reclamation Division in the Bureau of Geology of the Mississippi Department of Natural Resources, was contacted to obtain a list of all active clay mining companies in Mississippi. The various companies were called to request permission to sample their pits and stockpiles. In each case, permission was granted, and every known commercial clay operation was visited and sampled in the state. This included resampling the northern operations that were sampled in the 1986-87 study.

In every case, bulk material was taken from the company's stockpile. Since the stockpiles in some cases were admixtures from different pits, an attempt was made to obtain samples from each pit. This was not possible in several cases. Approximately 25 pounds of clay was obtained from each sample site.

The geographic locations of the sites where samples were collected are shown in Figure 2. The company and county in which the samples were obtained are listed in Tables I and II. Table I lists those sites that were sampled for this project. Table II lists the companies and property owners from which samples were taken in the 1986-87 study.

## LABORATORY TESTING

The field sampling and laboratory testing for this grant was done by Mr. Nicasio Lozano, a research graduate assistant, under the supervision of the author. The data is very reliable compared to the two past projects where a number of undergraduate and graduate students performed the testing as special student projects.

As noted earlier in the text, several in situ field tests were attempted with the hope additional correlative data could be obtained. The two in situ tests tried were a soil pocket penetrometer and a soil shear vane. Neither test was of any value. Since both test apparatus are designed for dense, in-place material, they could not be used for stockpile material, because it was disaggregated and weathered. The clays in the pits were shale-like and were too hard and strong for either apparatus to penetrate and function.

The laboratory tests consisted of conducting the liquid limit and plastic limit tests of the Atterberg Limits on each sample. If Mr. Lozano felt the test results were not indicative of the gross sample, he would make one or more test runs to substantiate the correct data. The tests were conducted in accordance with ASTM Standard D 4318-84 for the Atterberg Limits. Description and details of the tests are described in the 1986-87 Final Report.

## TEST RESULTS

The results of the ATterberg Limits tests are summarized in Table III. Also included in Table III is the commercial use of the clay, if known. The data are plotted on a Plasticity Chart, Figure 3. The commercial use of the clay is identified by different plotted symbols.

The new data confirms the interrelationship between the Atterberg Limits and the commercial use of clays, especially for bricks and for absorbents and bleaching.

The largest number of data points and the best grouping is for bricks. The Liquid Limits vary from a low of 25 percent to slightly less than 60 percent. The Plastic Index (Liquid Limit minus the Plastic Limit) spans from 7 to 30. The grouping falls into the soil classification category of "medium" plasticity and/or silty clays and clayey silts.

The second best grouping are the clays that are used as absorbents or for bleaching. Also known as Fuller's Earth, these clays are described in the literature as clays rich in the expanding clay mineral smectite (montmorillonite). Although no X-ray or other mineral identification was performed on the samples, the Atterberg Limits have numerical values that are consistent with smectite-rich clays. Compared to clays in which kaolinite and illite dominate, smectite-rich soils have very high Liquid Limits.

The areal extent of the absorbent and bleaching clays is much larger and the scatter of the data points is much greater in comparison to the brick groupings. However, it is well defined and bounded.

Two other groupings are evident even though the number of data points are small. Clays used for lightweight aggregate lie above the absorbent-bleaching group. More data points from other out-of-state, lightweight aggregate manufacturers would establish if this apparent grouping is valid.

There are only four data points for ball clays. However, these points on the Plasticity Chart are located in a very small area as can be seen in Figure 3. At the lower Liquid Limits and Plasticity Indices, the ball clays overlap the higher values for bricks. The apparent group does extend beyond the brick boundary but terminates before interfacing with the absorbent clays. As with the lightweight aggregate clays, the validity of this group can only be verified by more data points from other bah clay mines.

There is the possibility that other clay use groupings may exist. This study was limited to commercial clays in Mississippi and what the companies listed their product was used for either at an on-site plant or to whom the clay was shipped. As a result, not all commercial uses were identified in the study.

## SUMMARY AND CONCLUSIONS

The purpose of this research project was to verify the apparent correlation in the Atterberg Limits and the commercial use of clay which emerged from a previous small, limited study of clays in northern Mississippi. Although the number of data points were small, the previous study found that five clays used for bricks plotted on the Plasticity Chart in a very small area. Therefore, the author proposed a study to sample all the active commercial clay mines in Mississippi and conduct additional Atterberg Limit tests to get a statistically significant number of data points to assess the apparent correlation.

All known commercial clay mines in Mississippi were visited and sampled. In situ shear and penetration tests attempted at the site were not successful because the in-place clay beds were shale-like and had strengths that exceeded the apparatus upper limits.

Liquid Limits and Plastic Limits of the Atterberg Limits were conducted on the samples in the laboratory. The results of the test data were plotted on the Plasticity Chart and identified by symbol as to commercial use.

The apparent groupings of commercial use of clays on the Plasticity Chart was verified for bricks and absorbents/bleaching. The grouping for bricks is very well defined. The absorbent and bleaching clays exhibit a broader and more scattered pattern. Although only four data points exist for each, ball clays and lightweight aggregates have distinct areal groupings.

From the test results and the groupings of the data points on the Plasticity Chart, it has been demonstrated that the Atterberg Limits are an inexpensive, simple index test that can be used as a first evaluation of clay deposits being considered for commercial exploitation. The Atterberg Limits will indicate for what commercial use a clay deposit can or cannot be mined.

The Atterberg Limits also offer a very rapid and inexpensive way to evaluate the homogeneity and extent of a clay deposit. Since this test requires only a small amount of material, small diameter cores drilled across a prospective site are sufficient to make the analysis.

In summary, this investigation has demonstrated the Atterberg Limits are a viable test for exploration and initial assessment of clays for commercial use.

## REFERENCES

Aughenbaugh, N. B., 1987, "Basic Engineering Properties of Some Northern Mississippi Clay Deposits," Final Report, MMRI Grant No. 87-7F, Mississippi Mineral Resources Institute.

Aughenbaugh, N. B., 1988, "Evaluation of the Flexibility of Northern Mississippi Clays," Final Report, MMRI Grant No. 88-6F, Mississippi Mineral Resources Research Institute.

Murray, H. H., 1982, "Clay Resources of the Midwest States," Mining engineering, Vol. 34, No. 1, pp.68-71.

Patterson, S. H. and Murray, H. H., 1983, "Clays," Industrial Minerals and Rocks, 5 Ed., Vol. 1, SME of AIME, pp. 585-651.

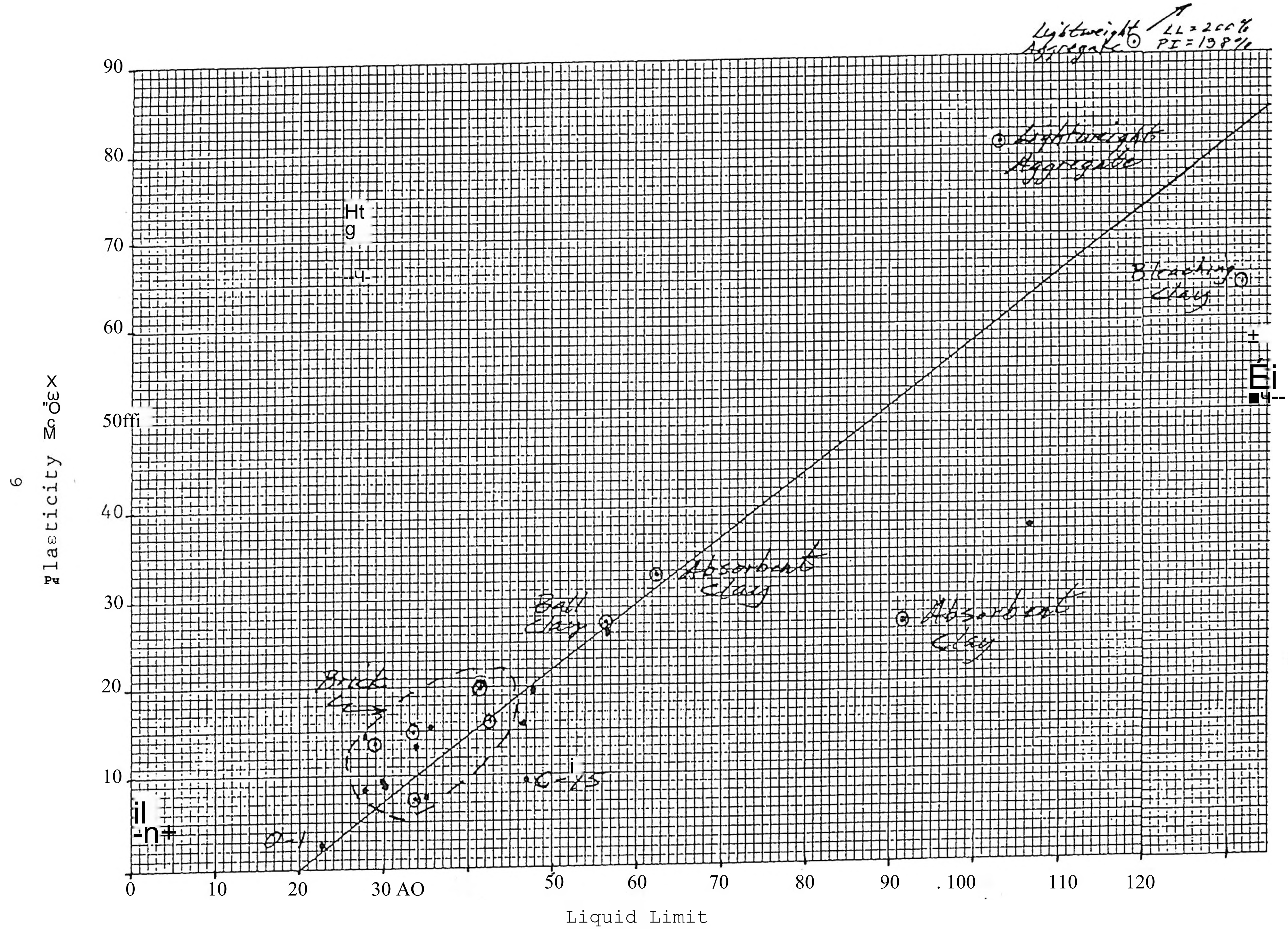

Lightweight Aggregate
LL = 200%
PI = 198%
Lightweight Aggregate
Bleaching Clay
Absorbent Clay
Ball Clay
Absorbent Clay
Brick
90
80
70
60
50
40
30
20
10
0
10
20
30
50
60
70
80
90
100
110
120
Liquid Limit

FIGURE 1

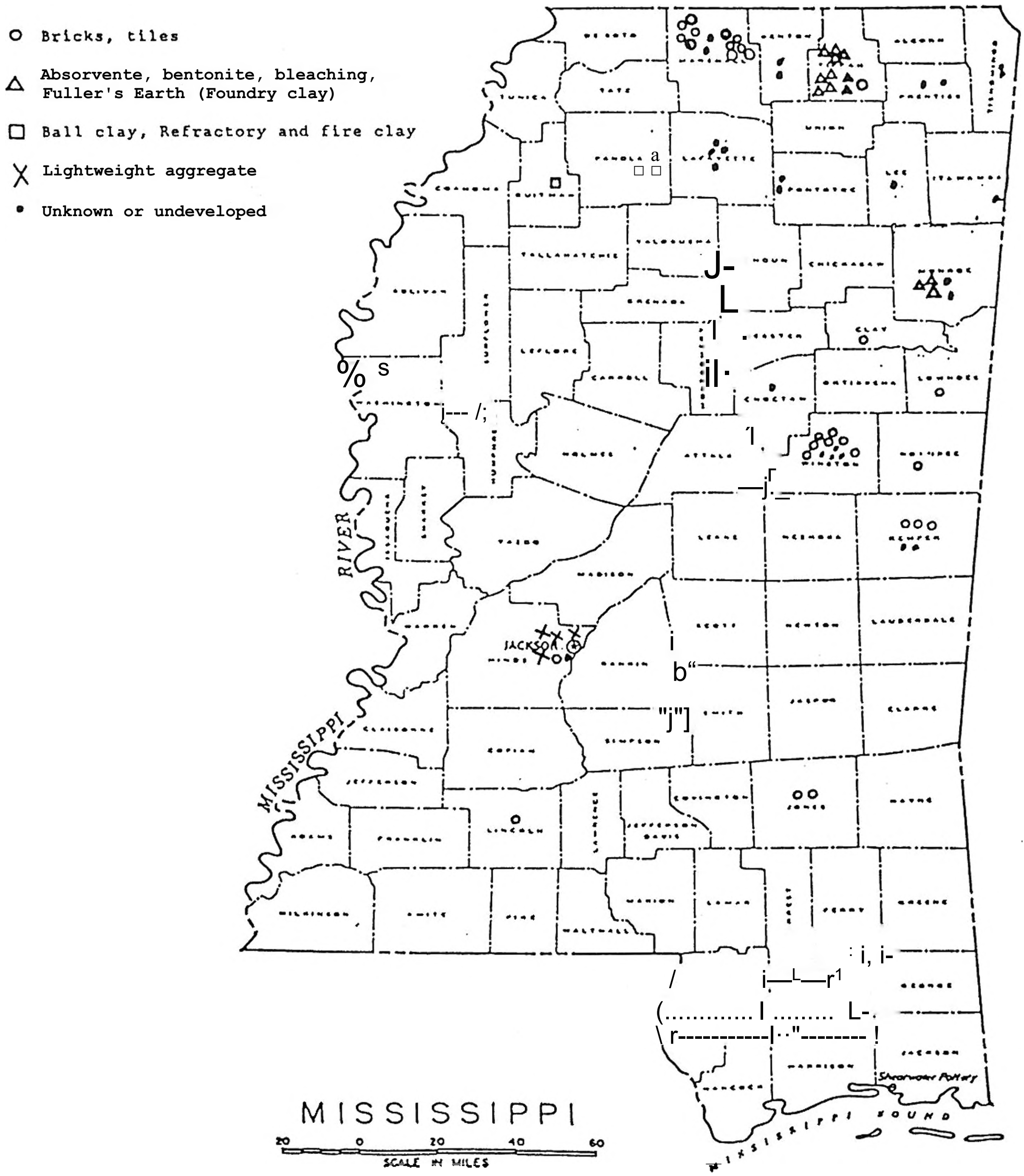
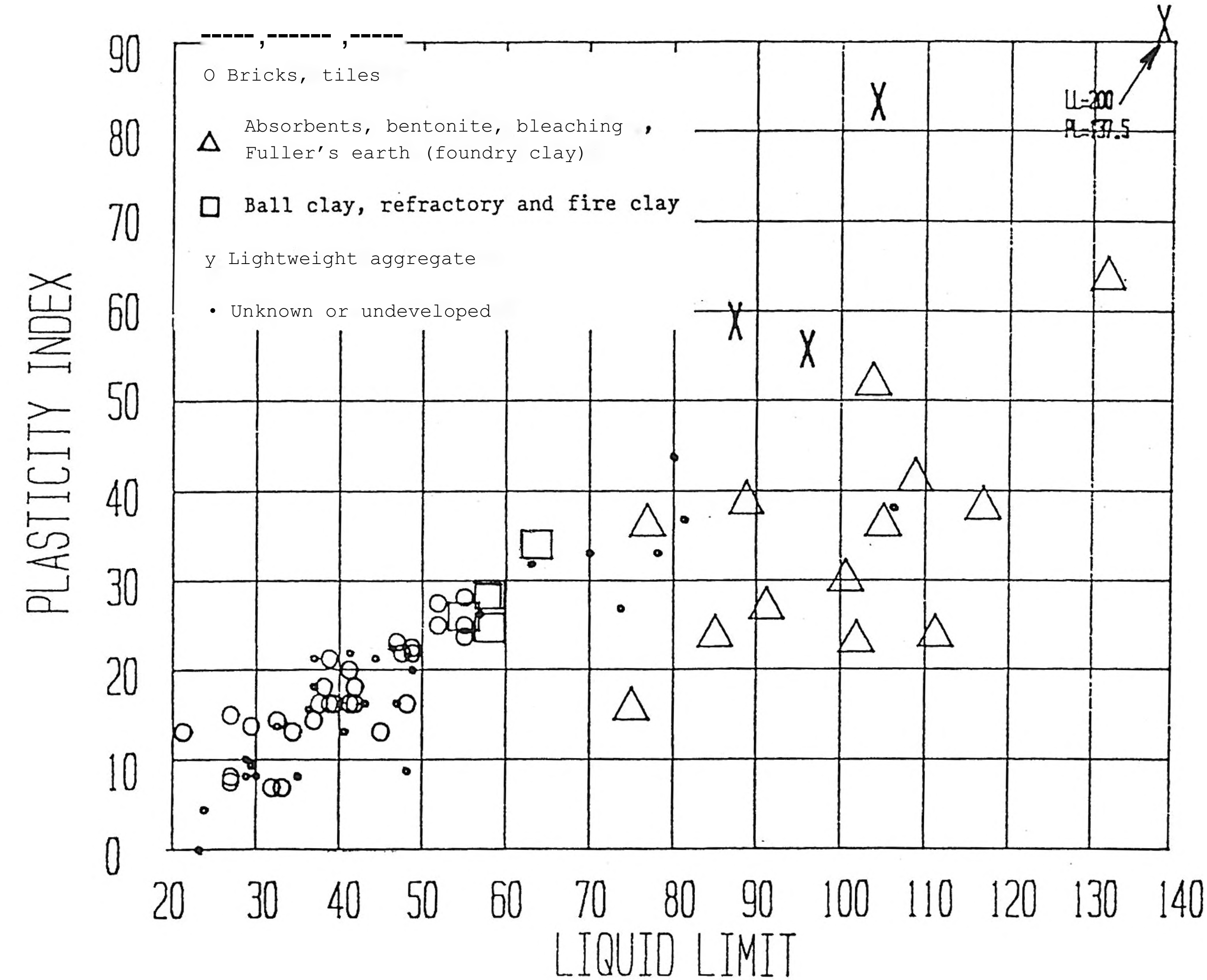

Bricks, tiles
Absorvente, bentonite, bleaching, Fuller's Earth (Foundry clay)
Ball clay, Refractory and fire clay
Lightweight aggregate
Unknown or undeveloped
JACKSON
MISSISSIPPI RIVER
MISSISSIPPI SOUND
Shearwater Pottery
MISSISSIPPI
20 0 20 40 60
SCALE IN MILES

Figure 2



O Bricks, tiles
Absorbents, bentonite, bleaching, Fuller's earth (foundry clay)
Ball clay, refractory and fire clay
y Lightweight aggregate
• Unknown or undeveloped
LL=200
PL=137.5
PLASTICITY INDEX
LIQUID LIMIT
0
10
20
30
40
50
60
70
80
90
20
30
40
50
60
70
80
90
100
110
120
130
140


Figure 3

TABLE I

List of Sample Hunber, Company and County

| Sample Humber | Coapany Kaве | Location (County) |
|---|---|---|
| Ml | Kentucky Clay Co. | Panola |
| И2 | Kentucky Caly Co, | Panola |
| K3 | Kentucky Clay Co. | Panola |
| K4 | Southern Brick & Tile | Marshall |
| H5 | Southern Brick & Tile | Marshall |
| K6 | Southern Brick & Tile | Marshall |
| K7 | Oil Dri Production | Tippah |
| K3 | Oil Dri Production | Tippah |
| N9 | Oil Dri Production | Tippah |
| KIO | Oil Dei Production | Tippah |
| Hil | Holly Springs Brick & Tile | Marshall |
| H12 | Holly Springs Brick & Tile | Marshall |
| K13 | Holly Springs Brick & Tile | Marshall |
| M14 | Unknown | Benton |
| H15 | INCORE Division | Tippah |
| И16 | IKCO8E Division | Tippah |
| H17 | Oil Dri Production | Tippah |
| Ì18 | Oil Dri Production | Tippah |
| И19 | Unknown | Prentiss |
| H20 | Unknown | Tishozingo |
| K21 | Unknown | Tishomingo |
| 822 | Unknown | Pontotoc |
| H23 | Unknown | Lafayete |
| 824 | Unknown | Itawaaba |

| | | |
|---|---|---|
| H25 | American Colloids | Oklahona |
| И26 | Aaerican Colloids | Monroe |
| Й27 | IMCORE Division | Monroe |
| 828 | Louisville Brick Co. | **Hinston** |
| И29 | **Colubus Brick Co** | Lowndes |
| ИЗО | **Colubus Brick Co.** | Clay |
| И31 | Coloabus Brick Co. | Winston |
| К32 | Louisville Brick Co. | Winston |
| ИЗЗ | Louisville Brick Co. | ïinston |
| К34 | Boydston Loaber Co. | Ïinston |
| 835 | Boydston Lumber Co. | ïinston |
| H36 | Boydston Luaber Co. | ïinston |
| H37 | Boydston Luaber Co. | ïinston |
| И38 | Delta-Macon Brick Co. | Hoxubee |
| 839 | Delta-Macon Brick Co. | **Keeper** |
| И 40 | Delta-Macon Brick Co. | Reaper |
| H41 | Delta-Macon Brick Co. | Reaper |
| И42 | Delta-Macon Brick Co. | **Keeper** |
| H43 | Delta-Macon Brick Co. | — |
| Й44 | Presley Oil Soak | Keeper |
| 845 | Presley Oil Soak | **Keeper** |
| И46 | Jacson Ready Mix | Hinds |
| И47 | Jackson Beady Mix | Hinds |
| H48 | Green Brothers Gravel Co. | Hinds |
| 849 | Tristate Brick Co. | Hinds |
| 850 | Tristate Brick Co. | Ïinston |
| 851 | Laurel Brick Co. | Jones |

| | | |
|---|---|---|
| K52 | Laurel Brick Co. | Jones |
| И53 | Boreal Brick Co. | Lincoln |
| K54 | Boreal Brick Co. | îinston |

| Sample Number | Property Owner | County |
|---|---|---|
| C-1 | Southern Brick & Tile | Marshall |
| C-2 | Southern Brick & Tile | Marshall |
| C-3 | Doss Brown | Marshall |
| C-4 | County | Marshall |
| C-5 | Holly Springs Brick & Tile | Marshall |
| C-6 | Holly Springs Brick & Tile | Marshall |
| C-7 | Holly Springs Brick & Tile | Marshall |
| C-8 | County | Lafayette |
| C-9 | Kentucky-Tennessee Clay Corp. | Quitman |
| C-10 | Unknown | Prentiss |
| C-11 | International Minerals Corp. | Tippah |
| C-12 | International Minerals Corp. | Tippah |
| C-13 | Melvin Posey | Lee |
| C-14 | Elizabeth Young | Choctaw |
| C-15 | Verbie Estis | Monroe |
| C-16 | Jackson.Ready-Mix | Hinds |
| C-17 | American Colloid Co. | Monroe |
| 0-1 | T.W. Bready | Benton |
| L-1 | Unknown | Monroe |
| K-1 | City of Oxford | Lafayette |
| K-2 | Unknown | Pontotoc |
| K-3 | Jackson Ready-Mix | Hinds |
| J-1 | City of Oxford | Lafayette |
| J-2 | International Minerals Corp. | Tippah |

TABLE ïl, List of Clay Samples

Table Ш- List of Sample Number, Plastic Limit, Liquid Limit, Plasticity Index and products.

| Sampi e Number | Pl asti c Li mi t | Li qui d Limit | Plasticity Index | Product |
|---|---|---|---|---|
| N1 | 30 | 64 | 34 | ball clay |
| N2 | 33 | 58 | 25 | ball clay |
| N3 | 28 | 54 | 26 | ball clay |
| N4 | 32 | 49 | 17 | bricks |
| N5 | 19 | 27 | 8 | bricks |
| N6 | 24 | 41 | 17 | bricks |
| N7 | 69 | 109 | 41 | absorbents |
| N8 | 87 | 111 | 24 | absorbents |
| N9 | 78 | 117 | 39 | absorbents |
| N10 | 60 | 75 | 15 | absorbents |
| N11 | 23 | 37 | 14 | bricks, tiles |
| N12 | 28 | 54 | 26 | bricks, tiles |
| N13 | 26 | 3*^ | 7 | bricks, tiles |
| N14 | 30 | 47 | 17 | undevel oped |
| N15 | 69 | 105 | 36 | absorbents |
| N16 | 70 | 1OO | 30 | absorbents |
| N17 | 52 | 104 | 52 | absorbents |
| NIS | 78 | 101 | 23 | absorbents |
| N19 | 18 | 28 | 10 | undeveloped |
| N20 | 24 | 45 | 21 | undeveloped |
| N21 | 0 | 23 | 0 | unknown |
| N22 | 45 | 81 | 36 | undeveloped |
| N23 | 19 | 37 | 18 | undeveloped |
| N24 | 16 | 37 | 21 | unknown |
| N25 | 50 | 89 | 39 | dessicant |
| N26 | 61 | 85 | 24 | bentonite, foundry clay |
| N27 | 40 | 76 | 36 | bentonite |
| N2S | 26 | 51 | 25 | bricks |
| N29 | 19 | 27 | 8 | bri cks |
| N30 | 24 | 52 | 28 | bricks |
| N31 | 22 | 41 | 13 | bricks |
| N32 | 32 | 45 | 13 | bricks |
| N33 | 25 | 42 | 18 | bricks |
| N34 | 36 | 80 | 44 | absorbents |
| N35 | 19 | 41 | 22 | bricks |
| N36 | 24 | 46 | 22 | bricks |
| N37 | 27 | 40 | 13 | bricks |
| N38 | 26 | 48 | 22 | bricks, tiles |
| N39 | 25 | 39 | 14 | bricks, tiles |
| N40 | 24 | 40 | 16 | bricks, tiles |
| N41 | 28 | 49 | 21 | bricks, tiles |
| N42 | 27 | 49 | 22 | bricks, tiles |
| N43 | 21 | 38 | 17 | bricks, tiles |
| N44 | 37 | 70 | 33 | absorbents |
| N45 | 45 | 78 | 33 | absorbents |
| N46 | 30 | 86 | 56 | light weight aggregate |
| N47 | 46 | 100 | 54 | light weight aggregate |
| N48 | 48 | 74 | 26 | gravel wash waste |

| | | | | |
|---|---|---|---|---|
| N49 | 22 | 35 | 13 | bricks |
| N50 | 31 | 55 | 24 | bricks |
| N51 | 20 | 38 | 18 | bricks |
| N52 | [illegible] | 47 | [illegible] | bricks |
| N53 | 18 | 39 | 21 | bricks |
| N54 | 27 | 56 | 28 | bricks |
| Cl | 15-2 | 29 | 13-8 | bricks |
| C2 | 26.2 | 42= 4 | 16-2 | bricks |
| C3 | 19.9 | [illegible] | 15-6 | unknown |
| C4 | 19.0 | 27.9 | 8.4 | unknown |
| C5 | 18.4 | 33=4 | 15 | bricks |
| C6 | 21 = 8 | 41.8 | 20 | bri cks |
| C7 | 26=5 | 33=8 | 7-3 | bricks |
| C8 | 20.4 | 29.9 | 9=5 | unknown |
| C9 | 29. 1 | 56-4 | 27.3 | ball clay |
| ClO | 69.3 | 106.8 | 37.5 | unknown |
| Cll | 29.6 | 62.5 | 32=9 | absorbents |
| C12 | 64.8 | 91.9 | 27. 1 | absorbents |
| C13 | 31.0 | 46.8 | 15=8 | unknown |
| C14 | 28. 1 | 47=8 | 19- 7 | unknown |
| C15 | 37.4 | 47 | 9-6 | unknown |
| Clb | 62.4 | 200 | 137.6 | lightweight aggregate |
| C17 | 68.3 | 132 | 63.7 | bleaching clay |
| Ol | 20= 1 | 22=9 | 2=8 | unknown |
| Ll | 27=4 | 35= 1 | 7.7 | unknown |
| K1 | 20.7 | 29,9 | 9.2 | unknown |
| K2 | 29=6 | 56-3 | 26.7 | unknown |
| K3 | 22 » 2 | 103 | 80-8 | lightweight aggregate |
| J1 | 19.7 | 33.9 | 14.2 | unknown |
| J2 | 13.3 | 27.9 | 14.6 | bricks |