

SOME CHEMICAL, PHYSICAL, AND  
MINERALOGICAL FEATURES OF SOIL COLLOIDS

by

J. H. Havens, Research Chemist  
J. L. Young, Jr., Research Geologist  
W. B. Drake, Research Engineer

Kentucky Department of Highways

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SYNOPSIS

The -1 micron portion of several diversified soils were separated by sedimentary fractionation. Physical properties were evaluated on the -1 micron portion, the +1 micron portion, and on the original -40 sample. The -1 micron portion was analyzed for clay mineral identity by X-ray diffraction, and analyzed chemically for associated materials such as the oxides of Iron, Aluminum, Calcium, and Magnesium.

These data present several possibilities and trends as to the inter-dependency of the involved variables. Other considerations have been devoted to the geologic origin of several samples and to various physico-chemical relationships.

INTRODUCTION

Each component or ingredient in a natural soil mixture embraces a series of variables of a physical and chemical nature. Combinations, either natural or synthetic, of these ingredients accordingly involve a multitude of variables which

may contribute in part or in whole to the resultant physical properties of a soil.

The physico-chemical phenomena associated with soil colloids and near-colloids have been under exploitation by various investigators since the discovery of the crystalline nature of soil colloids by Hendricks and Fry (1) in 1930. Although cation exchange in soil colloids had been observed as early as 1850 by both Thompson (2) and Way (3), the work was generally predicated on the misconception that soil colloids were of the character of hydro-gels of silicic acid, and of oxides of iron, and aluminum. The results of this early work are now manifest in modern concepts of clay mineralogy and associated cation exchange. The problem of ascribing properties beyond a definite crystalline structure to an unknown clay is, even today, a laborious and tedious task complicated by isomorphic replacements and uncertainty as to the purity of the specimen under study. However, it has been shown by recent investigators (4) that clays which were once described under various names are actually isomorphs of one of the mineralogical "families" of clays. These families are characterized by discrete ranges with respect to cation exchange capacity, height of the unit cell as determined by X-ray diffraction, silica-sequi-oxide ratios as determined by chemical analyses, and their accommodation for water. Of these families, the names Kaolinite, Illite, and Montmorillonite have been widely accepted and applied to those most frequently associated with soils.

These clay minerals represent only one portion of soils, and in any study attempting to define the physical or

engineering properties of soil, it is necessary to examine all constituents and variables, both individually and collectively. There must be at least one of these variables which can be held accountable for the difference in physical properties of any two random samples. Further, by exhaustive analysis of all constituents, it should be possible to determine the relative dependencies of these variables on the resultant physical properties. Only by a thorough understanding of these mechanisms will it ever be possible to prescribe the most favorable stabilizing treatment for soil categories.

These problems have been under study in Kentucky for two years. The first report (5) on this work was presented at the 28th Annual Meeting of the Highway Research Board in 1948. That report described in detail a fundamental method of investigation and a limited tabulation of data. During the past year the method of investigation was modified in favor of simplicity and adaptability to survey work. Results reported previously indicated the possibility of soils derived from Ordovician formations in Kentucky being characterized by containing only Illite as the clay mineral ingredient. Kelley (6) indicates that even the random occurrence of a single clay mineral in a soil is not only rare, but highly improbable. The possibility of such occurrence has been further investigated and reported in this paper.

Endell, Loos, and Breth (7) prepared synthetic mixtures of clays and quartz sand which demonstrated the effect not only in percentage of clay present but differences in type of clay plus the effect of the exchangeable cation in the clay

with respect to the Atterberg Limits. It was shown that by increasing the clay content, there resulted an increase in the Atterberg Limits, but the increase was not linear. These results were obtained from the use of relatively pure clays, whereas soil colloids are generally mixtures of clays or a clay and other colloidal materials.

Were soils composed of inert granular material and a pure clay, positive correlation could most certainly be obtained, as in the experiment by Endell, et. al.; However, in natural soils, such variables as mixtures of clays, organic impurities, soluble salts, colloidal sesqui-oxides, variations in gradation, silicic acid gels, and cation exchange introduce multiple complexities. Further, with respect to the exchangeable cations, it cannot be stated with certainty that a clay contains only one type of cation even in a relatively concentrated environment of any single cation. Although the equilibrium may be shifted, in complex colloids of soils the assumption of complete replacement must be treated with caution.

The purpose of this study was to make an objective investigation of these colloidal constituents and their effect upon the engineering properties of soils through analyses for clay mineral content and identification of the mineral suite, analyses for associated sesqui-oxides and other so-called impurities, and by the performance of physical tests on the composite soil species as well as the individual fractions.

## MATERIALS AND PROCEDURES

Thirty-two of the soils were selected from samples obtained in a study of the pumping action of rigid pavements in Kentucky (8). These samples were selected on the basis of variety of physical characteristics and geologic distribution. In addition 16 miscellaneous samples of unknown origin, and all but two representing unusual features in other states and some foreign countries, were included.

Because of limitations in the amount of soil available, no attempt was made to determine physical characteristics other than the Atterberg Limits of the sixteen special soils. Results of classification tests on the 32 Kentucky soils are tabulated in Table 1.

Recovery of -1 micron Fraction - Two hundred to five hundred grams of soil passing the No. 40 Sieve were taken as a sample from which the -1 micron fraction was extracted by gravity separation as described in the previous report on Separation Fractionation and Mineralogy of Clays in Soils.\*

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\* See p. 470, Proceedings - Highway Research Board, V. 28, 1948

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The -1 micron material was recovered from the accumulated suspension by precipitation with Sodium Chloride. The amount of this salt added was just enough to bring about complete flocculation and precipitation in 24 hours.

Note - Some soils required considerably more salt than others, yet in most cases the supernatant liquid rarely tasted salty. It was also observed that many soils which were initially reluctant to go into suspension, invariably entered into suspension after several successive washings with distilled water.

The -1 micron material was recovered after precipitation by decantation and dried by evaporation under mild heat and air. On drying, the soil had occluded salt crystallized on the surface, but this could be washed away without disturbing the material. This dried material was pulverized in a mortar to pass the No. 200 sieve.

It was elected to use Sodium Chloride as the precipitating agent in view of its relative inability to replace natural cations other than Potassium and Lithium. The actual effect of the NaCl on the natural cations is not definitely known, and it is not known whether the concentration of  $\text{Na}^+$  necessary to bring about precipitation is in excess of the concentration necessary to produce appreciable shift in the replacement equilibrium of the natural cation whether monovalent or divalent. In any case, it must be conceded that the possibility of alteration of the natural clay is very high, and it may be further stated that any other electrolyte used would produce a similar alteration unless the natural cation were identifiable in advance and the electrolyte to be added were a soluble salt of the same cation.

Kelley, (6) in a discussion of the effect of NaCl saturation on a clay, indicates that  $\text{Na}^+$  saturated soils tend to be more impermeable than  $\text{Ca}^{++}$  saturated soils; whereas,  $\text{Ca}^{++}$  saturated soils tend to be more granular due to the binding together of the clay particles.  $\text{Na}^+$  soils are more dispersed. He also infers that when large numbers of soils are compared, the correlation between percentage of  $\text{Na}^+$  saturation and physical properties is often found to be poor. It can be shown by

the data in Table 2 that there was present in each sample of the -1 micron fraction, almost without exception, a sufficient amount of  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  to satisfy the adsorbed cation capacity. In that connection, it is possible that the NaCl served primarily to reduce the Zeta - potential of the double layer (9) and consequently to reduce the hydration of the adsorbed cation, thus bringing about coagulation without involving appreciable cation exchange. If that was the case, the NaCl altered the electrolytic condition of the suspending medium without replacing the exchangeable cation of the clay.

Chemical Analysis - After essentially all of the material -1 micron in size had been separated from the -40 soil, a 0.5 gram sample of the -1 micron material was extracted with dilute HCl with mild heat and the extract analyzed gravimetrically for  $\text{R}_2\text{O}_3$ , CaO and MgO. Volumetric determinations for  $\text{Fe}_2\text{O}_3$  were made by reduction of the iron with Stannous Chloride and titrating with  $\text{KMnO}_4$  solution. The percentage of  $\text{Al}_2\text{O}_3$  was estimated by subtracting the percentage of titrable  $\text{Fe}_2\text{O}_3$  from the percentage of  $\text{R}_2\text{O}_3$ . Aliquot portions of the extract are being held in reserve for determinations of  $\text{Na}^+$  and  $\text{K}^+$ , and it is not possible to present those data in this report.

The residues from the extractions were dried and weighed. These results are reported in Table 2 as Approximate Percentage Clay by Extraction. The sums of all the determinations subtracted from 100 per cent is also reported in Table 2 as the Approximate Percentage Other Material. Attempts were made to estimate the amount of organic material remaining in the

residue from the extraction by further extraction with organic solvents, and in several instances appreciable quantities could be recovered by evaporating and solvents from the extract; but after extraction by this method, it was not possible to obtain clear X-ray diffraction patterns on the residue. That, of course, is very indicative of organic impurities. Only after treatment with 30 per cent  $H_2O_2$  was it possible to obtain clear patterns, indicating that the extraction of the organic materials by solvents was by no means complete.

Mineralogical Analysis - After extraction by HCl and organic solvents followed by treatment with  $H_2O_2$  to oxidize the remaining organic material, X-ray diffraction patterns were made on the purified residue from each sample. These patterns were used for identification of the clay mineral groups present. Samples of one clay identified as an Illite-Kaolinite mixture by X-ray diffraction methods were analyzed by the differential-thermal method.

Physical Tests - Physical characteristics were defined mainly by the Atterberg Limits on the composite -40 sample, the -40 to +1 micron fraction, and the -1 micron fraction. In some cases an insufficient quantity of sample made it necessary to omit some of the Limit tests. Sieve and hydrometer analyses and Atterberg Limits tests on the -40 material had been made in previous investigations pertaining to the 32 Kentucky soils. None of the 16 special samples was tested for grain-size distribution; therefore, in any of the graphical presentations of results involving percentages of material finer than certain



size, these 16 samples are not represented. The same is true, of course, for any particular relationship involving any sample when one of the tests for that relationship was necessarily omitted because of insufficient material.

## RESULTS AND ANALYSES

Essentially all of the pertinent data resulting from these tests and analyses are shown in Table 1 through Table 3. Graphical presentations of the data are supplemented in many instances by statistical evaluations of the resulting relationships. Only those relationships worthy of discussion are considered in this report.

Natural Soil -40 - Relationships resulting from physical tests on the soils finer than the 40-mesh sieve were not unusual with respect to the amounts of material finer than 5 microns; nor was there any significant effect of the type of clay mineral. This is demonstrated in Figure 1 where it is indicated that the Liquid Limit increases in a manner exceeding a direct proportionality with increases in the percentages of -5 micron material. Both this and the relation shown in Figure 2 conform generally with accepted and established concepts of the influences from these fine portions of the soil mortar. However, the significance of extropolation of the curves back to the ordinate intercepts or origin should not be overlooked. In the case of Figure 1, it is indicated that if the percentage of -5 micron material is reduced to zero the average soil would be expected to have a Liquid Limit of zero; and the possibility for variation from this trend is limited by the grouping of

<u>Sample Number</u>
212
213
235
236
238
243
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271
274
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300
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377
382
383
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395
398
410

\*R

Sample Number				Mineralogical Analysis (X-Ray Diffraction)		
	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	R <sub>2</sub> O <sub>3</sub>	Approximate Percentage		
				Koalinite	Illite	Montmorillonite
212	6.00	11.30	17.30	40	60	--
213	11.86	6.24	18.10	10	90	--
235	1.56	2.80	4.36	100	--	--
236	15.64	8.46	24.10	40	40	20
238	4.50	7.48	12.03	--	100	--
243	2.60	7.83	10.43	--	100	--
247	13.20	7.78	21.00	--	100	--
271	18.00	3.32	22.20	40	60	--
274	5.29	11.98	17.27	40	60	--
289	8.48	6.72	15.20	--	100	--
297	3.80	3.13	6.98	40	60	--**
300	7.27	2.14	9.41	70	30	--
301	10.82	4.18	15.00	50	50	--
302	7.20	4.60	11.30	50	50	--
305	11.30	13.70	25.00	50	50	--
310	12.02	5.88	17.90	50	50	--
337	3.62	3.80	7.42	80	20	--
341	28.30	4.97	33.30	--	100	--
350	11.79	5.11	16.90	--	100	--
359	19.26	3.24	13.50	--	100	--
377	16.60	9.65	26.20	--	100	--
382	12.27	4.83	18.10	80	20	--
383	16.24	7.16	23.40	30	70	--
386	0.36	5.70	6.06	60	40	--
389	11.00	7.66	18.70	50	50	--
390	1.12	10.10	11.22	50	50	--**
391	4.36	4.52	8.88	50	50	--
392	14.90	7.96	22.90	30	70	--
394	9.50	7.46	17.00	40	60	--
395	12.30	7.34	19.64	50	50	--
398	3.62	3.12	6.74	--	--	--
410	1.68	3.12	4.80	50	50	--**
D-59	6.27	1.37	7.64	--	--	--
21	18.19	4.71	22.90	33-1/3	33-1/3	33-1/3
48-B	16.40	9.58	26.00	50	50	--
F-4	9.66	5.76	15.42	--	--	--
B-104	29.10	3.38	32.50	60	--	40
F-39	20.70	1.94	22.60	--	100	--
F-37	13.60	7.01	20.60	--	100	--
B-155-1	3.20	4.12	7.32	--	100	--**
B-144-C	21.20	1.82	23.00	10	90	--
B-30	6.92	6.20	12.12	40	60	--
B-3-C	9.10	6.32	15.42	--	--	--
78-A	12.30	6.89	19.20	--	50	50
1-A-B	9.20	5.98	15.18	10	90	--
50	6.49	11.89	18.38	--	100	--
28	1.87	8.25	4.12	--	100	--
18	11.50	4.90	16.40	--	100	--**

\* Approximate percentages

\*\* Indication of Quartz.

TABLE 3

## PHYSICAL PROPERTIES OF FRACTIONS

Sample Number	-1 Micron				-40 to +1 Micron			
	L.L.	P.L.	P.I.	S.L.	L.L.	P.L.	P.I.	S.L.
212	---	53.5	---	20.4	---	---	---	25.0
213	90.2	27.8	62.4	20.5	26.4	13.0	13.4	16.0
235	57.2	29.7	27.5	24.0	---	---	---	---
236	103.0	29.6	73.4	11.0	---	---	---	---
238	85.2	31.9	53.3	23.0	36.3	22.8	13.5	23.5
243	41.1	20.2	20.9	13.7	---	---	---	---
247	81.9	34.9	47.0	35.0	---	---	---	---
271	95.8	30.9	64.9	10.0	30.9	26.1	4.8	23.0
274	100.0	32.8	67.2	24.5	---	---	---	---
289	88.2	28.5	59.7	22.0	33.3	26.6	6.7	22.0
297	34.1	18.9	15.2	18.7	---	---	---	---
300	36.7	20.83	15.9	39.0	---	---	---	---
301	79.6	30.48	49.1	21.0	---	---	---	---
302	---	25.1	---	44.2	---	---	---	---
305	---	51.27	---	24.3	---	---	---	---
310	---	23.6	---	27.5	---	---	---	---
337	---	29.4	---	---	---	---	---	---
341	---	---	---	---	---	---	---	---
350	68.5	30.7	37.8	25.8	32.4	26.3	6.1	26.0
359	76.2	30.97	45.2	44.5	---	---	---	---
377	---	37.9	---	19.6	24.0	18.1	5.9	19.0
382	71.0	38.9	32.1	26.8	---	---	---	---
383	81.0	33.88	47.1	24.0	---	---	---	---
386	---	18.8	---	44.6	---	---	---	---
389	75.6	31.93	43.7	28.1	---	---	---	---
390	79.2	30.6	48.6	9.5	20.0	17.5	2.5	17.0
391	82.2	35.6	46.6	22.0	---	---	---	---
392	97.5	34.7	62.8	23.0	25.8	18.3	7.5	21.0
394	---	34.4	---	28.3	---	---	---	---
395	---	33.1	---	43.4	---	---	---	---
398	---	23.0	---	37.9	---	---	---	---
410	44.0	25.0	19.0	24.7	---	---	---	21.0
P-59	68.5	49.63	18.9	22.0	---	---	---	---
21	---	37.4	---	17.6	---	---	---	---
48-B	124.0	48.3	75.7	15.0	---	---	---	---
P-4	---	34.2	---	---	---	---	---	---
H-104	67.2	37.4	29.8	24.0	---	---	---	---
F-39	52.4	30.8	21.6	16.1	---	---	---	---
F-37	87.4	31.15	56.2	24.0	---	---	---	---
D-153-1	51.5	29.1	22.4	8.0	---	---	---	---
B-144-C	68.3	34.3	34.0	23.4	---	---	---	---
B-30	80.4	52.8	27.6	29.1	---	---	---	---
B-3-C	---	---	---	---	---	---	---	---
78-A	85.9	33.03	52.9	4.0	---	---	---	---
1-A-B	81.8	26.45	55.3	23.0	---	---	---	---
50	75.9	34.67	41.2	15.5	---	---	---	---
28	96.3	31.1	65.2	17.0	---	---	---	---
18	---	45.2	---	---	---	---	---	---

LIQUID LIMIT - 40  
vs  
PER CENT - 5 MICRON MATERIAL

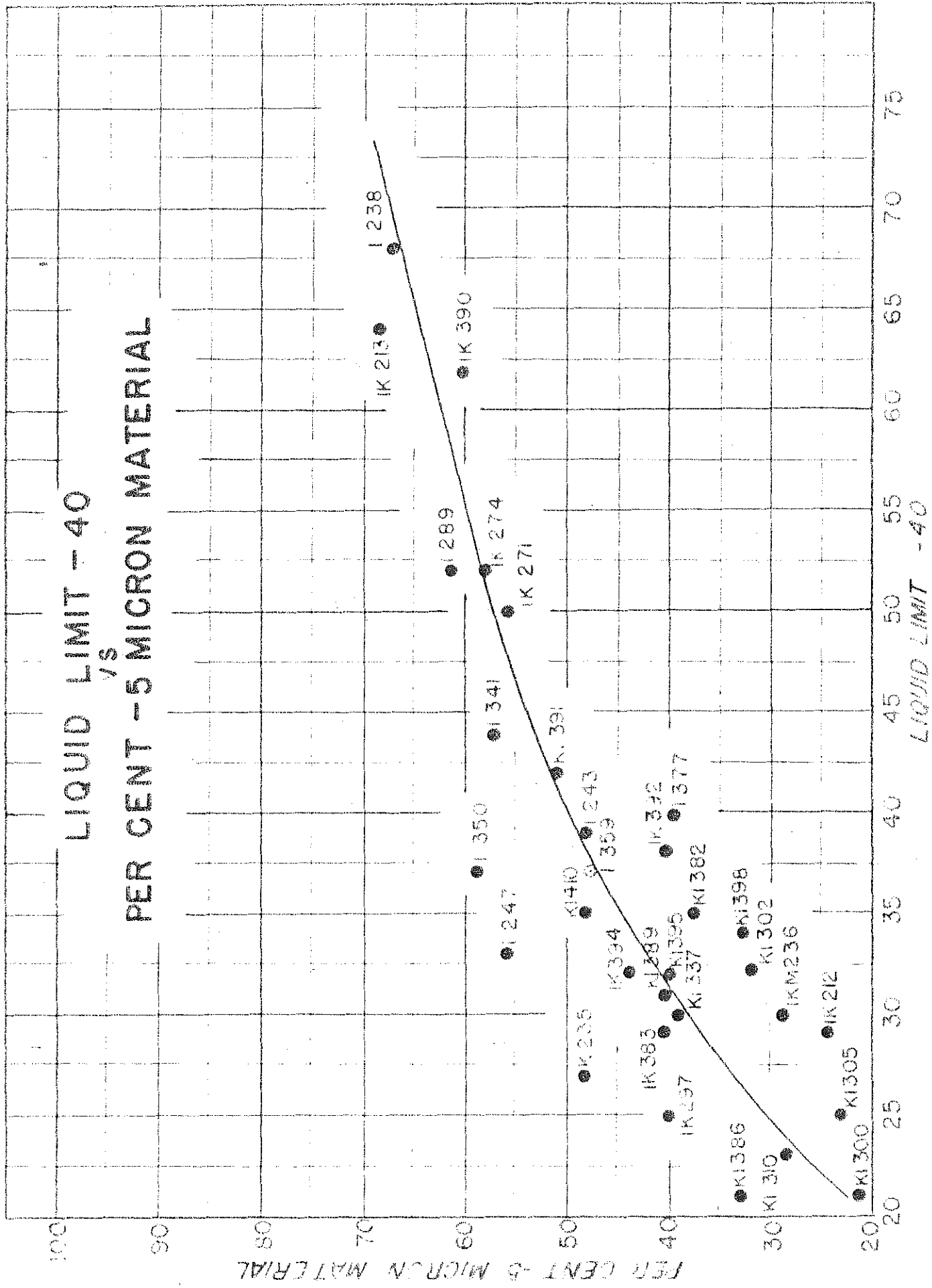


Figure 1

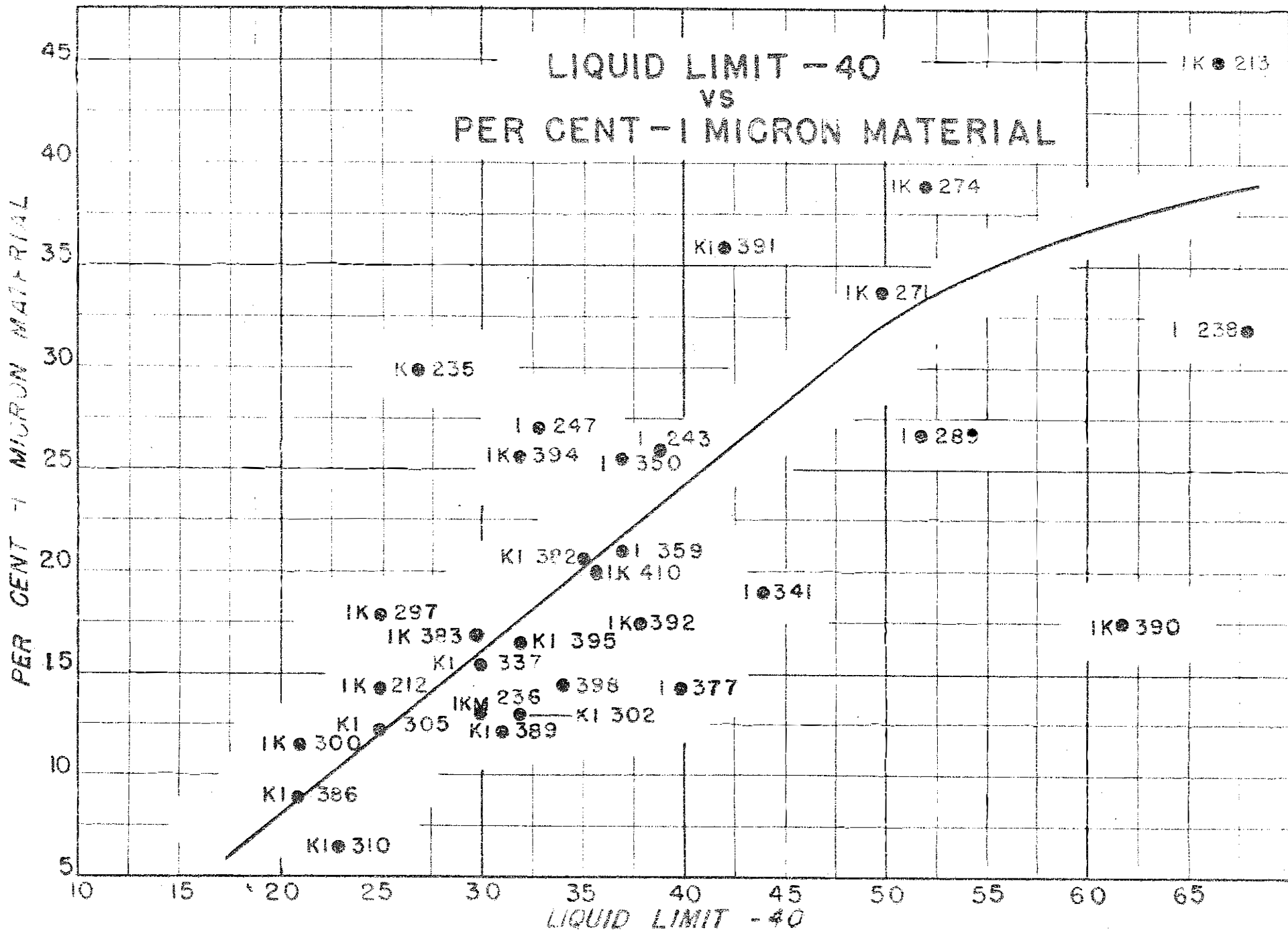


Figure 2

the plotted points as well as by the average conditions represented by the curve. When Figure 2 is considered in the same light; on the extrapolation of the curve to the intercept, a certain value for the Liquid Limit is retained after the amount of  $-1$  micron material is reduced to zero.

Perhaps the most significant feature resulting from these and similar plots relative to other properties is the absence of any characteristic which can be consistently ascribed to the influence of clay minerals. The highly kaolinitic clays do usually have lower values of plasticity, but mixtures of Illite and Kaolinite exhibit random distribution which cannot be held to account by any of the information obtained thus far. It must be considered, however, that these influences in certain natural soils may be obscured by other variables such as sorting and the so-called contaminating ingredients; and that the physical properties shown are, in fact, summations of all influences. In a general way, the influences of any particular component should probably be described in terms of an intensity factor and a capacity factor, intensity representing the reactivity of the ingredient and capacity representing the amount of material contributing; all of which must be evaluated by differentiation of the individual components.

$-40$  to  $+1$  micron Fraction - That part of the soil between the  $40$ -mesh sieve and  $1$  micron in size was generally more erratic than the soil as a whole insofar as relationships between different physical properties are concerned. The limited number of tests performed on this size material does not permit

extensive evaluation of any individual property; but from general inspection of the limits for this size-range in Table 3 as compared to the equivalent values for the -40 soil in Table 1, it must be concluded that the manifestations of plasticity have been all but eliminated by the extraction of the -1 micron fraction. This, of course, does not imply that plasticity of a soil can be explained by such a simple observation as this, but it does emphasize the dependency of granular soils - and even soil mortars - on the colloid and near-colloid sizes for its plastic qualities.

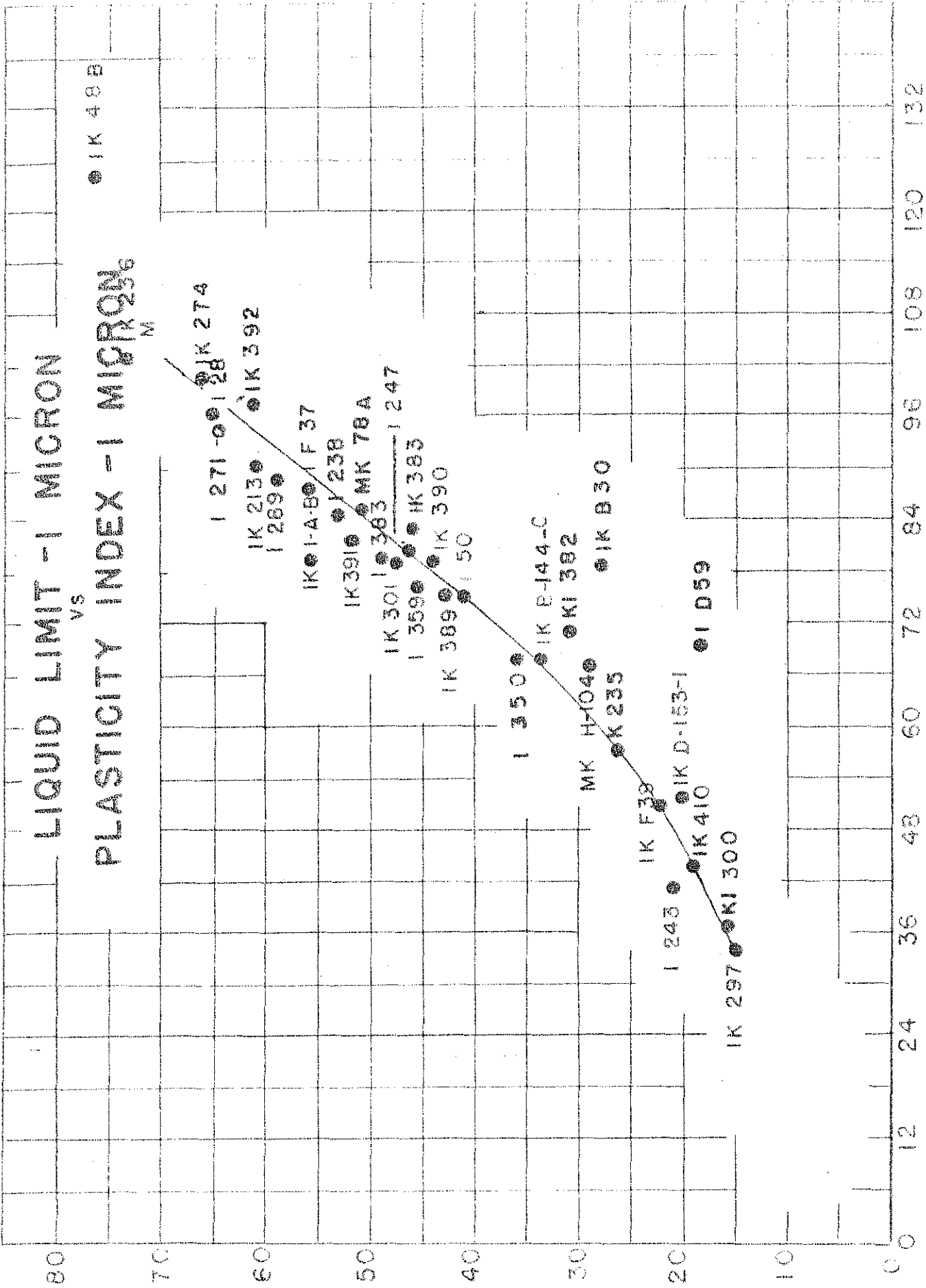
In all but two of eight cases represented, the Liquid Limit, Plastic Limit and Shrinkage Limit were nearly equal, and in those two cases the amount of material finer than the 5 micron size was unusually large.

-1 micron Fraction - When the -1 micron fraction is separated from the coarser material of the natural soil, the properties of these colloidal plasticizers may be tested independent of the coarser materials. Also, by virtue of greater homogeneity with respect to size, the relationships between the Atterberg Limits may be defined more precisely. All the results from physical tests on this fraction are reported in Table 3.

The resulting relationship between Liquid Limit and Plasticity Index is illustrated graphically in Figure 3. A statistical test of these data yields a relationship of 0.940 for Pearson's linear correlation coefficient, whereas a coefficient of unity would indicate perfect linear correlation between the two variables.



PLASTICITY INDEX - 1 MICRON



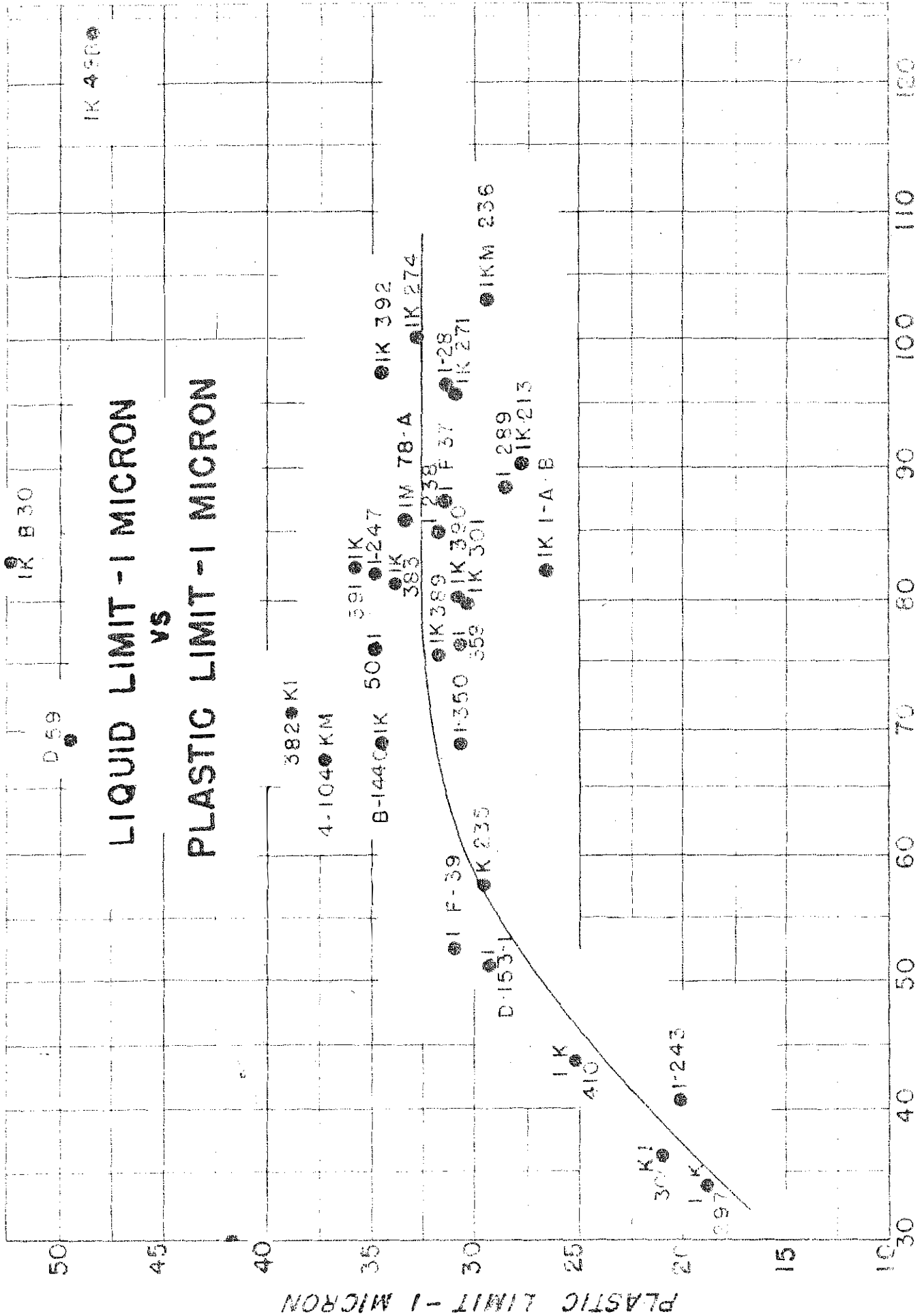
LIQUID LIMIT - 1 MICRON  
Figure 3

The relationship between Liquid Limit and Plastic Limit shown in Figure 4, is a matter of further interest and should probably be considered the more fundamental relationship. The inference made here may be better understood from consideration of the proportionality between Liquid Limit and Plastic Limit up through values of approximately 65 per cent and 32 per cent respectively; and then, the absence of any further increase in Plastic Limit for further increase in Liquid Limit. In view of these considerations the plot of Liquid Limit versus Plasticity Index (Fig. 3) in the lower range describes the proportionality mentioned while in the upper range it is essentially a description of the Liquid Limit plotted against itself, the abscissa being measured Liquid Limit values and the ordinate being values of Liquid Limit after subtraction of the relatively constant Plastic Limit.

It may be noted that samples D59, B30, and 48B had exceptionally high Plastic Limits - around 50 per cent - which might be expected for a Na-Montmorillonite; but by X-ray diffraction analysis, B30 and 48B were shown to be Illite-Kaolinite mixtures. There are no significant features shown in Table 2 by which to explain these high Plastic Limits; however, some features not considered (such as organic matter) could possibly account for the discrepancies.

Components of -1 micron Fraction - The preceding discussions have been devoted to the physical properties of the soils and their size - fractions in order to emphasize the influence of the colloid and near-colloid materials. There was further

# LIQUID LIMIT - 1 MICRON VS PLASTIC LIMIT - 1 MICRON



LIQUID LIMIT - 1 MICRON  
Figure 4

differentiation of the -1 micron fraction by mineralogical and chemical analyses. The results of these analyses are listed in Table 2.

To consider the problem here in a general way, clays in soils may be likened unto filter - media which tend to retain various contaminating materials through the infiltration of water. Further, they tend to retain adsorbed surface materials. These ingredients may function in many cases to alter the physical properties of the mass beyond the limits accountable by physical properties of the clay minerals alone. The analytical results in Table 2 demonstrate variations in some of these associated materials, as well as, the mineralogy of the clay ingredients.

It is apparent that determinations of  $\text{Fe}_2\text{O}_3$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$ , and  $\text{CaO}$  plus the clay residue, in most cases, do not suffice to describe all the ingredients present. As a result of this, the unknown quantity was calculated and designated as Percent Other Material. The mere existence of this unknown indicates the necessity for more exhaustive analyses. As previously stated, considerable amounts of organic material, presumably capable of saponification, was obviously associated with the fine fraction of some soils, but means were not available to analyze for it quantitatively.

Probably the most significant relation resulting from comparison of these data with the physical properties of the -1 micron fraction is manifest in a tendency for the Liquid Limit and Plasticity Index to increase as the percentages of either  $\text{R}_2\text{O}_3$ , or  $\text{Fe}_2\text{O}_3$  increased. These characteristics are

illustrated graphically in Figure 5 through Figure 8. The resulting tendencies must be considered as more than a random occurrence; but for the present explanation of the actual mechanism producing the relationships can be made only by speculation.

It is very probable that Iron and Alumina are reduced by nature to colloidal sizes, and such an admixture in soil - merely by virtue of its size - would exert an influence on properties of a soil. In addition, oxides of Iron and Aluminum tend to form hydroxide-gels, depending on the prevailing acid or alkaline conditions, and it is conceivable that these oxides may be transformed from a solid or soluble salt to a gelatinous state simply by dilution. The transition would also be expected to be reversible. For this reason, the possibility of the existence of these hydro-gels of Iron and Aluminum is of no minor concern. Such a factor should be considered in any attempt to evaluate the properties of soil colloids where Iron and Alumina appear as accessory ingredients to clays.

Clay Mineralogy and its Areal Aspects - Fifty-four different Kentucky soils have been analyzed for their clay minerals. These samples were chosen to represent a spread geographically, geologically, topographically and pedologically. See Figure 9. Diverse combinations of clay minerals have been found and it appears to be the exception for a single clay mineral to be in existence in a soil.

Attempts have been made to show that the mode of origin of a soil or its parent material has a tendency to produce a



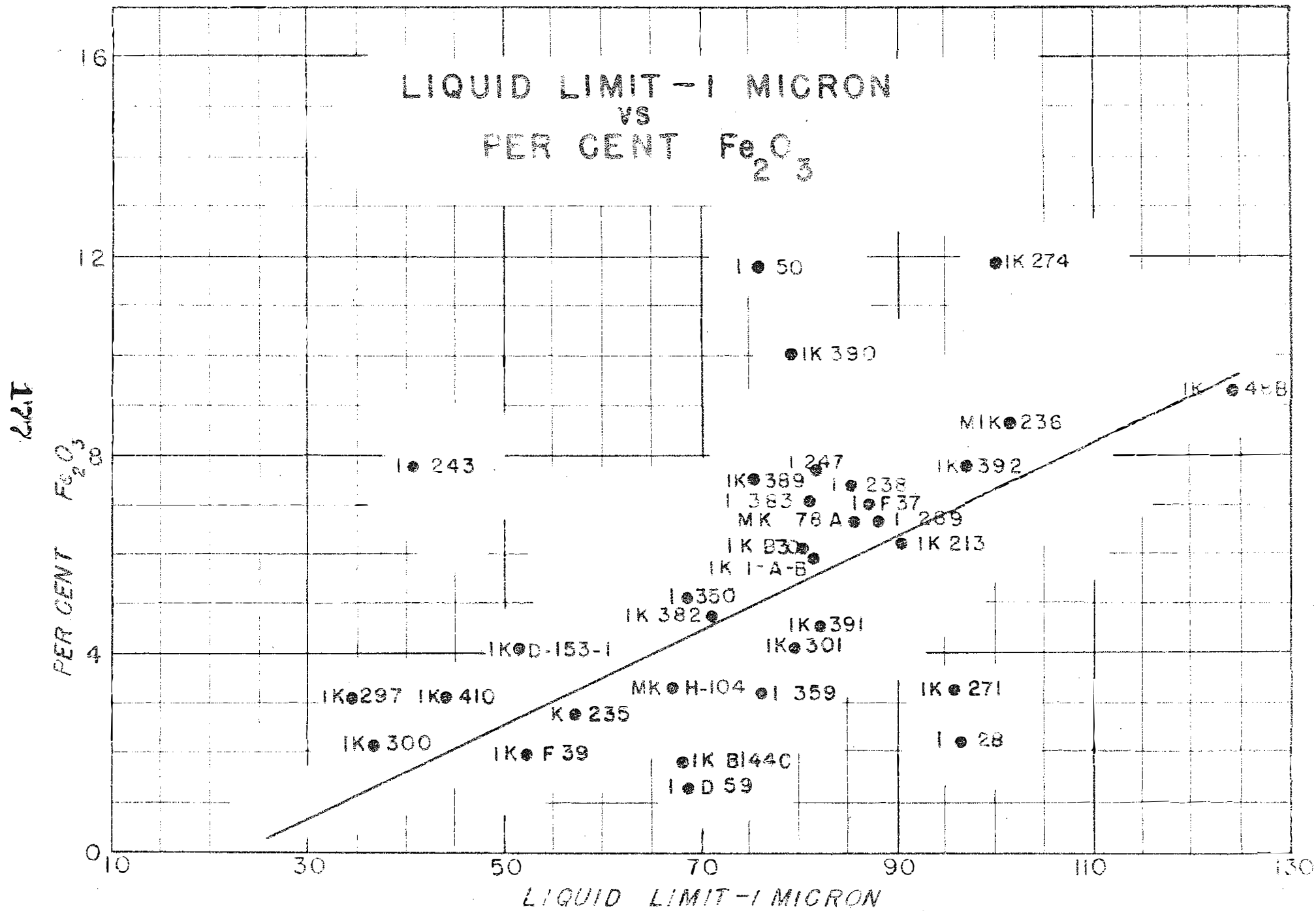
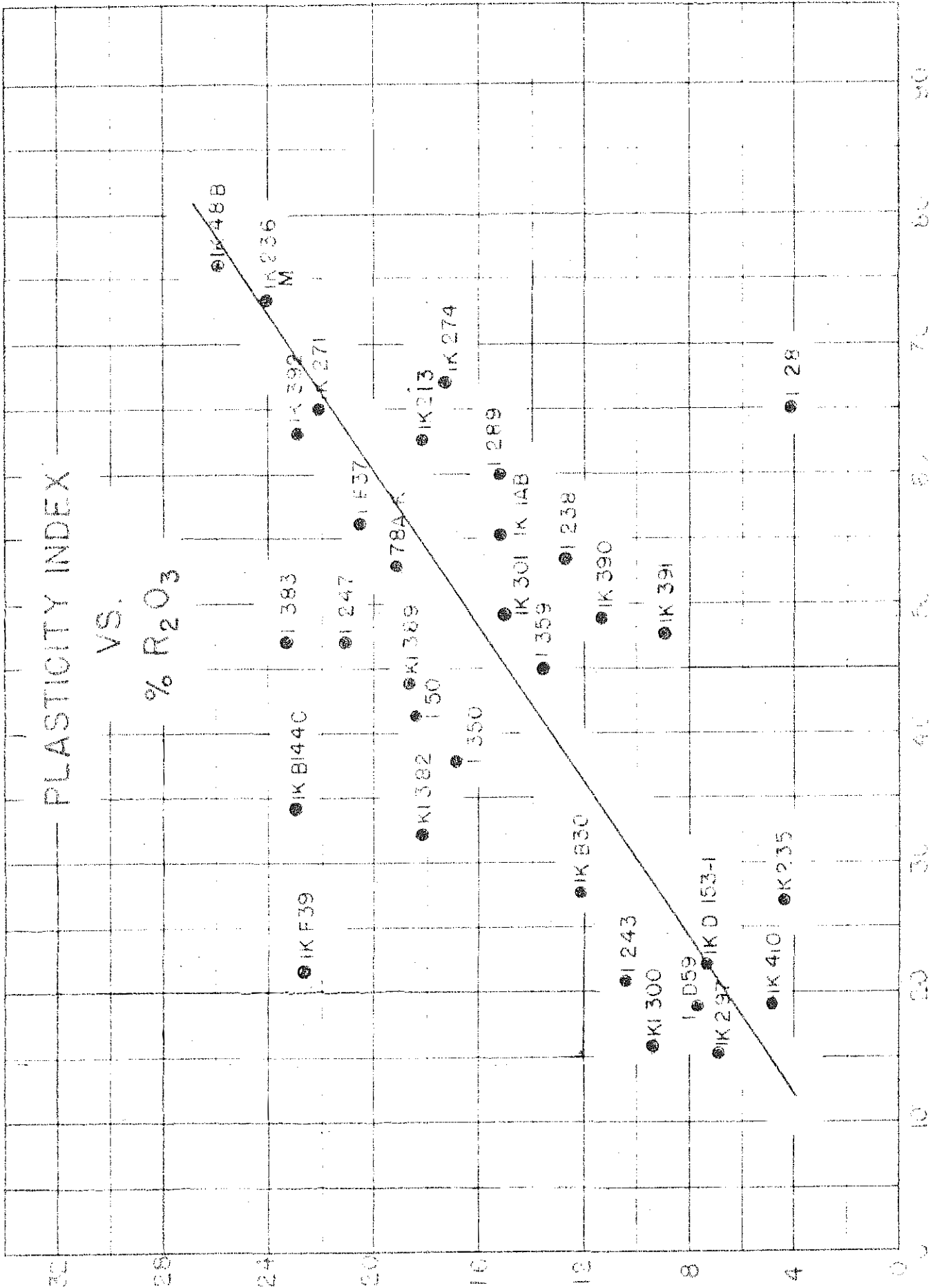


Figure 6

PLASTICITY INDEX

VS.

% R<sub>2</sub>O<sub>3</sub>



PLASTICITY INDEX - I/MICRON

Figure 7



PLASTICITY INDEX - 1 MICRON

vs

PER CENT  $Fe_2O_3$

12

10

8

6

4

2

0

IK 274

IK 390

IK 247

IK 383

IK 289

IK 213

IK 350

IK 391

IK 301

IK 359

IK 271

IK 297

IK 300

IK 410

IK F-39

IK 228

IK B-144-C

IK D-59

IK 48-B

IKM 236

IK 392

IK 243

IK 389

IK 258

IK 383

IK 289

IK 213

IK 350

IK 391

IK 301

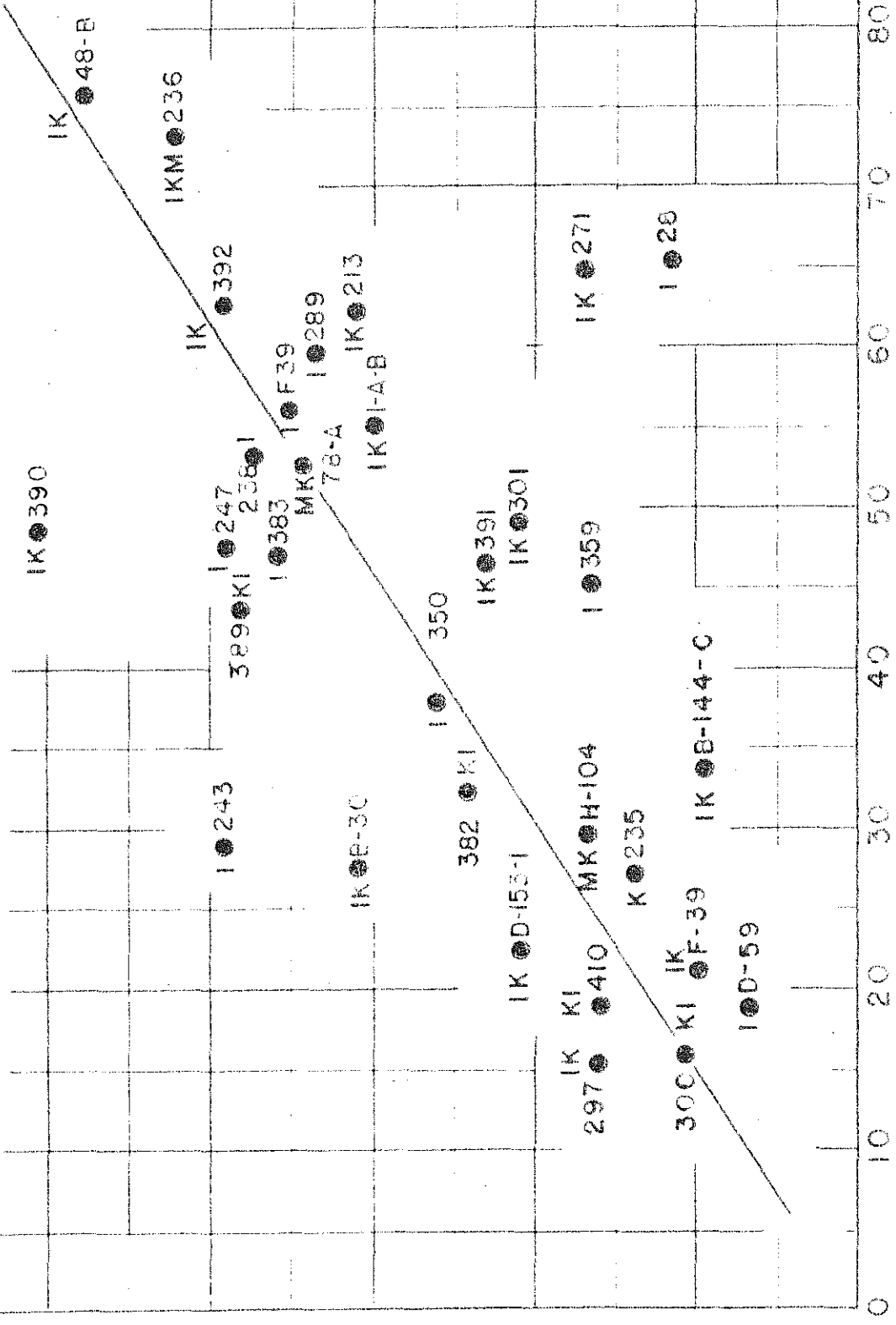
IK 359

IK 271

IK 228

IK B-144-C

IK D-59



characteristic clay mineral. Thus far, only the soils in the Blue Grass Region of Kentucky - derived principally from Ordovician limestone and shale formations - have borne this out. Sixteen soils from this region all contained Illite exclusively, and only one other soil sample analyzed showed this feature.

Note- Those locations having other clay mineral identities and included within this region on the map in Fig. 9, actually represent alluvial deposits in the Ohio River Valley or outliers of Silurian and Devonian formations. These could not be set apart on a map prepared at this scale.

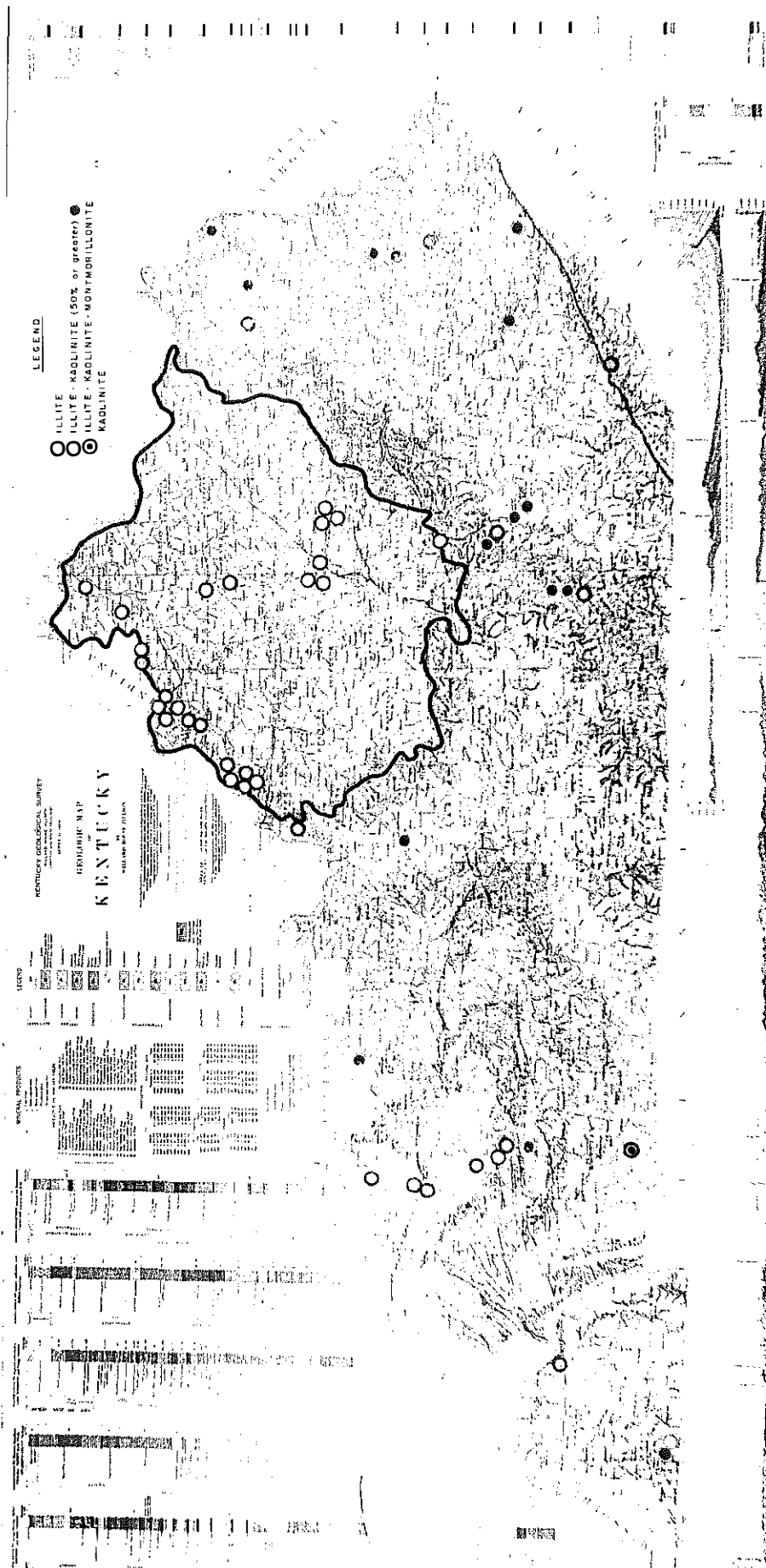
However, soils derived from younger formations have shown no tendency to be characterized by clay minerals. It can be shown that the Blue Grass Region contains no exclusive features other than age of formations and their structural aspects. Although general geologic regions of Kentucky have not been covered completely, there is evidence suggesting a unique situation in the Blue Grass area.

Efforts were made to detect possible areal variations of Iron, Aluminum, Calcium, and Magnesium oxides that were determined. Iron and Calcium oxide content was shown to be relatively constant in the Blue Grass Area but varied without regard to any known aspects outside this region.

No soil-area differentiated pedalogically, showed exclusive clay mineral content but this aspect was not explored with the detail thought necessary. Future work might well include a more specific analysis of this type. These observations are in anticipation of substantiating data, but are nevertheless interesting points worthy of discussion.

Figure 9, Geologic Map of Kentucky Showing Clay Mineral Identity and Distribution of 54 Soil Samples

Note: The general boundaries of the Ordovician are shown by heavy line.



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