A Comparison of Soils on Unreclaimed 1949 Indiana Coal Stripmine Surfaces in 1964 and 1981

John Richard Schrock
Association of Systematics Collections
University of Kansas
Lawrence, Kansas 66045
and
Jack R. Munsee
Department of Life Science
Indiana State University
Terre Haute, Indiana 47809

Introduction

In 1964, Munsee (10) studied the ecology of ants on relatively barren unreclaimed Indiana spoil banks originally deposited in 1949-51. In 1981, Schrock (15) repeated the methodology at the same 21 sites, now mostly revegetated. While the primary focus of both studies was the surface active insect populations, extensive samplings of both the soil and vegetation at each site were used in analyses to explain the distribution of selected insects. Of these major factors studied by Munsee and Schrock—soils, vegetation, and insects—this paper summarizes the soil data.

Since there is variation in 1) the amount of sulfur compounds in the parent material, 2) the climate and particularly the available moisture, and 3) the mining techniques, there is variation in the pH ranges found on coal stripmines. Previous studies (5, 13, 19) have all assumed that changes over time could be studied at one point in time on a series of multi-aged spoil banks, but this approach may be limited because of different initial pH values. The Munsee and Schrock studies, 17-years apart, constitute the first real-time comparison of changes on humid Midwestern spoil banks over a substantial period of time.

Methods

In 1964, Munsee selected an ecological study area in the old Sunspot Mines. The location of the stripmines is south of Centenary in Vermillion County, Indiana, in Township 14N, Section 24(10). An unnamed rangeline road runs north and south and intersects State Road 163 which connects Clinton with Centenary. The old stripmines border the rangeline road one mile south of this intersection. The study area is 0.366 km (1200') west of the rangeline road and is mapped in Figure 1.

The spoilbanks resulted from surface coal mining by Ayrshire Colleries from 1949 to 1951. Ayrshire sold about 300 acres of the spoilbanks to the Clinton Chapter of the Isaac Walton League. The protection provided by the League and the relative inaccessibility of the research site have prevented disturbance of the research site over the past 41 years.

Site Descriptions

Twenty-one research sites, 19 on mined spoilbanks and two in an adjacent unmined area, were selected by Munsee in 1964 with guidance from Dr. Leland Chandler from Purdue University. The plots were selected to provide a similar age of spoils and an assortment of exposures and slopes (Figure 1, Table 1). In addition each site needed to provide sufficient area and accessibility to conduct the research.

The size and shape of plots varied due to topography but the two insect pitfall traps placed in each plot were located along the center line in all cases (Figure 2).

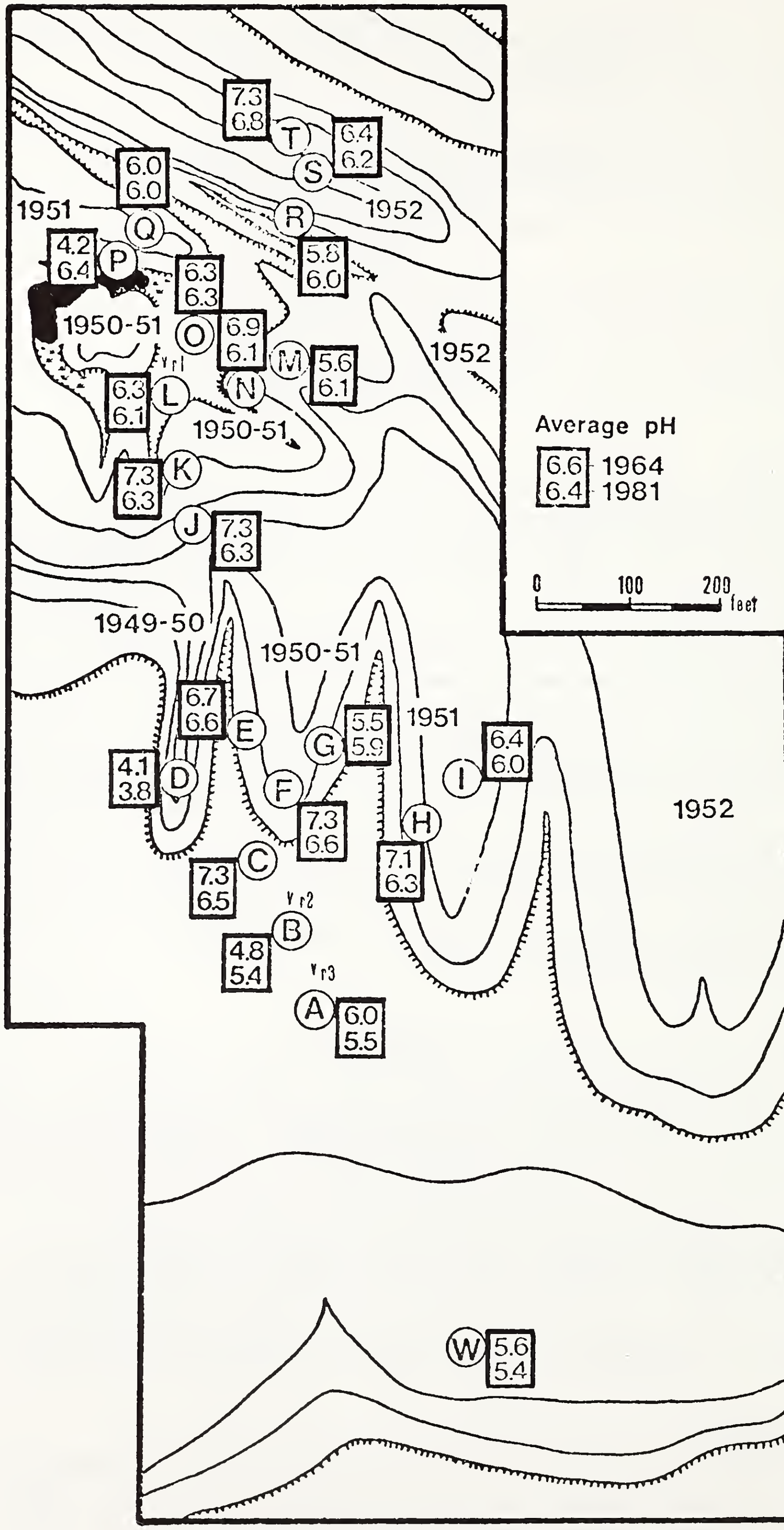

FIGURE 1. Map of physical features in research area. Contours are not surveyed but merely represent an approximation of the topography. The age of the spoilbank ridges is given by year mined. Average site pH for both study years is given in the box tangent to the research site label.

TABLE 1. Physical features of the twenty research sites sampled in 1964 and 1981. Exposure, slope and plot size are taken from Munsee's 1964 measurements. Solar radiation level were calculated from Bufoo et al. (8) according to the exposure and slope of each site.

RESEARCH SITE	AGE+ (Years)		EXPOSURE 360°circle		SLOPE (%)	AREA (sq. meters)	PLOT SIZE (Feet)	DAILY SOLAR RAD.*	ANNUAL SOLAR RAD.**
W	unmined		155	SSE	22	113.8	35 x 35	799	233398
A	unmined		135	SE	4	452.9	75 x 65	839	207225
B	14	31	290	WNW	7	250.8	60 x 45	828	192962
C	14	31	155	SSE	10	92.2	32 x 31	833	220118
D	14	31	92	E	52	146.3	45 x 35	643	161680
E	14	31	235	SW	56	146.3	45 x 35	604	211457
F	14	31	160	SSE	59	81.3	35 x 25	535	239559
G	14	31	90	E	58	113.8	35 x 35	606	154046
H	13	30	255	WSW	61	241.6	65 x 40	591	180892
I	13	30	165	SSE	3	181.2	65 x 30	840	207398
J	14	31	350	N	9	185.8	50 x 40	818	175920
K	14	31	345	NNW	51	167.2	45 x 40	491	063947
L-O	14	31	340	NNW	2	204.4	110 x 20	838	196585
M	13	30	130	SE	7	167.2	60 x 30	836	211182
N	13	30	295	WNW	18	34.8	25 x 15	797	178027
P	12	29	210	SSW	50	69.7	30 x 25	618	233645
Q	12	29	305	NW	7	111.5	40 x 30	825	187165
R	12	29	225	SW	52	139.4	50 x 30	634	216188
S	12	29	320	NW	7	162.6	70 x 25	825	187165
T	12	29	30	NNE	35	81.3	35 x 25	659	102617

+Age of site in 1964 and 1981. *Cal./cm^2/day. **Cal./cm^2/year.

Plots were often oriented to avoid stagnant ponds, ravines and unmanageable slopes. However, in spite of avoiding problematic areas, this still sampled a variety of positions, centering the pitfall traps on tops, slopes and bases of ridges and defining the location of soil samples. Detailed notes and a sketch map drawn by Munsee in 1964 proved vital in 1980 when Schrock proposed a follow-up study at the site. In spite of extensive revegetation in 1981, natural landmarks permitted Munsee to locate the pitfall trap locations and reestablish plots. The correct position, to within several feet or closer, was confirmed for most sites by tree counts taken in 1981.

Slopes

Slope at each site was determined by an Abney level in 1964. In spite of erosion, the topography was assumed unchanged in 17 years and slope measurements were not repeated in 1981. Visual inspection of the sites appeared to verify this assumption.

Site Orientation

Orientation of each slope was measured by a pocket compass with magnetic north the reference in 1964. This direction was considered unchanged in 1981. Theoretical daily and annual solar radiation were calculated from exposure and slope according to Buffo et al. (4). Since the research area was at 39 degrees and 40 minutes north, the 40-degree-table data could be used with less than 0.5% error. Values in Cal./sq.cm./day and Cal./sq.cm./year were extrapolated to the nearest degree slope within the appropriate aspect (i.e., NNW, ESE, etc.). Daily solar radiation values were calculated for each site on June 22, the approximate mid-point in the study periods.

Stage Designation

In 1964, Munsee designated his research sites by letters, beginning with "Site A" in the south end of the area and working north along the mined ridges and west to east when sites cut across ridges (Figure 1). Originally, "Site A" was the only unmined site. But several weeks into his study, Munsee added an unmined woodland site, "Site W," south of site A. Therefore, sites labelled by letters close together in the alphabet are physically closer together on the research area, with the exception of site W which is off the spoilbanks from Site A. This explains why tabular data on sites is presented in this study in the order "W, A, B, C, D . . . T."

Soil Acidity

In 1964, Munsee collected ten soil samples from each site. With only sites W and A extensively vegetated, the sampling procedure on bare ground posed little disturbance to plants or the surface-active fauna. His samples were extracted with a soil probe to a depth of 30.5 cm. (one foot). These 2.5 cm. diameter (one inch) cores were taken at four equally-spaced points along each diagonal of the site. Two additional samples were taken at a ". . . .convenient distance on either side of the point of crossing of the two diagonals." The general scheme is given in Figure 2 although

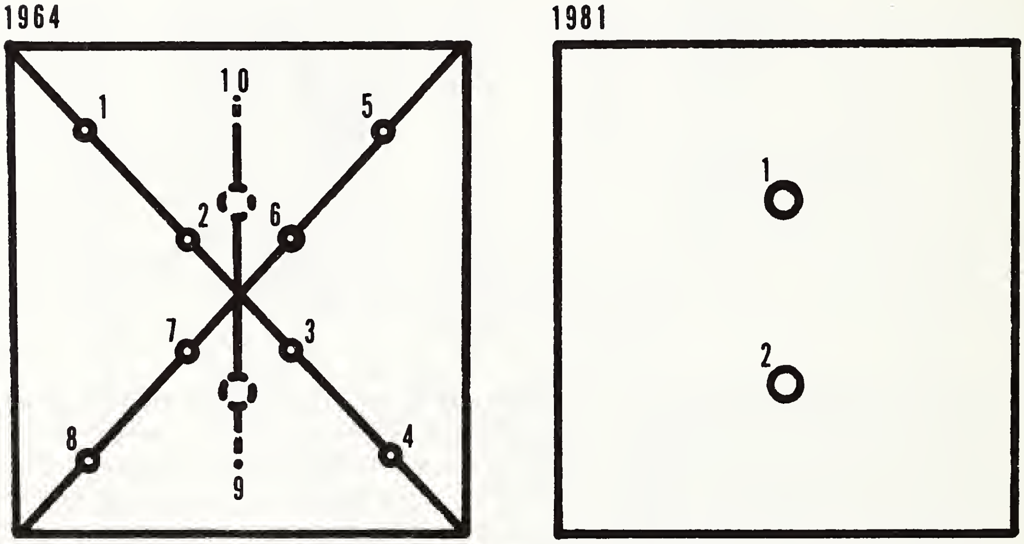

FIGURE 2. Patterns of soil sampling used in the two research years. The rectangular sites varied in size and proportions. Although the cores on the 1964 diagonals were equally spaced, they could not be relocated with accuracy. 1 through 10 are soil sample cores; pitfall traps are along midline.

the distance between cores varied widely with the different-sized research sites. For each of the ten cores, soil acidity was tested, usually on site but occasionally upon returning to the laboratory, using Purdue University quick-test reagents and color charts. At each core site, the surface material and material at 15.2 and 30.5 cm. (six and 12 inches) were tested. This provided values at three depths at each of ten points. Only rarely did boulders prevent a full 30 readings per site.

In 1981, this same sampling pattern was not replicated for two reasons. First, while the pitfall trap locations themselves were relocated with some assurance less than a meter from their 1964 positions, the placement of the cores on unmeasured diagonals and at a "convenient distance" along the meridian meant that the 1981 core samples could be from one to three meters distant from the original 1964 core sites. Even more importantly, vegetation and a thin organic layer had developed at all but site D. Sampling ants with pitfall traps, Greenslade (7) found that such mechanical disturbances of organic soil greatly distorted the pitfall catch of ants in the area. Likewise, Joosee (8) found disturbances altered springtail sample numbers and traced the hyperactivity of these insects to increased carbon dioxide resulting from any soil disturbance increasing the respiration by soil microorganisms. These effects would be minimal while the spoils were generally barren but had to be considered significant in 1981. Since this research effort was mainly directed at accurately re-sampling surface-active arthropods (11), and since the 1964 cores were not marked for relocation, it was decided to make no soil disturbance beyond the minimum required for setting the pitfall traps in the ground. However, since the traps required a 20.3 cm. diameter (eight inch) core, four samples were taken from the core, both at the surface and from the 15.2 to 30.5 cm. (six to 12 inch) layers.

In 1981, soil samples were stored in marked plastic bags and returned to the laboratory. Two of the four samples taken were tested at the surface and again at the six to 12 inch layer. Soil was mixed with distilled water at a lg.:1ml. ratio and stirred with a glass rod. A Corning Digital 109 General Purpose pH Meter was used to measure the pH, after the electrodes were allowed to equilibrate from five to 15 minutes. We recognize Smith and Sobek's (16) concern that pH readings with the electrode placed in a soil suspension sediment (vs. supernatent fluid) are usually lower. However, this would only shift the results and not change the relationships (Figure 4).

Soil Moisture and Infiltration

A field capacity test as described by Meyer and Anderson (9) was run by Munsee in 1964. Soil from the core samples was air-dried and the large soil aggregates were broken by a mortar and pestle. Particles larger than 0.495 mm. diameter were excluded from the test. The soil was tamped into a 500 ml. graduated cylinder. A standard quantity of water (100 ml.) was added at the top and the depth of penetration was recorded for each of seven days. Comparable quantities of soil from 20 cylinders, one sample from each research site, wetted to field capacity, were weighed and oven-dried at a low setting (about 38 degrees C, 103 degrees F) for 24 hours. Percent moisture content was calculated on an oven-dry soil basis. The same methodology was used in 1981. In addition, in 1981 an attempt was made to layer the column with material from a similar horizon. Since soil at each level (surface, 15.2 cm. and 30.5 cm.) had been bagged separately, it was possible to place 30.5 cm. soil at the bottom of the cylinder and surface soil at the top. It was found that the inner diameter of 500 ml. graduated cylinders varied slightly. Since depth of water penetration is determined by the soil's ability to hold water, the depth reading was adjusted to compensate for more or less soil volume. The precise internal diameter of the 1964 cylinders is not known.

Soil Texture

The separation of soil fines into sand, silt and clay fractions was done using the Bouyoucos (2) method for both 1964 and 1981 samples. The one inch (2.5 cm.) soil cores did not always provide sufficient soil for both the pH and texture analyses in 1964 and additional cores were gathered. Since an organic layer was essentially absent from the mined sites in 1964, this extensive soil sampling probably did not disturb the strip mine biota. In 1981, the texture samples were drawn from the 15.2 and 30.5 cm (six and 12 inch) layers.

In both years, hydrogen peroxide was used to remove organic matter where it was found in appreciable amounts. Soil samples were dried, soil aggregates broken and all particles larger than 2 mm. were sifted out using soil sieves. Fifty grams of soil were carefully weighed and transferred to a flask of 100 ml. of 5% sodium hexametaphosphate (Calgon). This was shaken occasionally and allowed to stand overnight so that all aggregates could slake.

The following day the soil suspension was poured into a modified blender and mixed for two minutes. The suspension was transferred to a Bouyoucos cylinder and agitated with a metal churn. The Bouyoucos hydrometer was immediately inserted and readings were taken at 40 seconds and 6 hours 52 minutes.

Since the hydrometer reading varies with temperature, temperature readings were made with each recording in 1981 and 0.36 units were added to or subtracted from the hydrometer reading for each degree above or below 20 degrees C respectively. Aside from the temperature corrections, we feel the texture tests were conducted identically. Operator bias between 1964 and 1981 of course can never be ruled out.

Clustering Methods, Correlations and Principal Components Analyses

As a part of a broad ecological study, physical features of the stripmine sites were defined as the pH, percent bareground, water capacity, maximum water penetration, percent silt, percent clay, plant hits and tree basal area (as architectural features), annual and daily solar radiation, and slope.

To detect the complex patterns of similarity between sites based on physical features, a cluster analysis was performed using each site as a case. For this task, BMDP statistical program P2M was used as modified to run on the Kansas University Computing Center Honeywell DPS-3/E.

The distance between two cases of data is defined as the chi square test of equality of the two sets of frequencies. The computer program begins by comparing each pair of cases and using this chi-square test, joins the closest two cases. When two cases are joined, a new centroid is formed by averaging each variable. In the next round of searching for the shortest distance, this centroid is compared with other candidates for membership to the next larger cluster. The number of cases (or pseudo-cases) is reduced by one at each step until all are clustered.

It is also possible to estimate the influence of these physical factors from the combined effect of all factors using principal components analysis. For this task, BMDP statistical program P4M was used as modified on the K.U. system mentioned above.

TABLE 2. Soil pH values from sample cores at various depths in both 1964 and 1981 at three sites. Values for 1964 from Munsee's unpublished field data. (*) acid slick. S = Surface. 6″ depth = 14 cm.

SITE P 1964 — 2.54 cm. (1") Sample Core #

	1	2	3	4	5	6	7	8	9	10
S	5.6	4.2	3.8	4.6	3.8	3.8	3.8	4.2	6.2	5.0
6"	6.6	4.2	4.2	3.8	3.8	3.8	3.8	3.8	4.6	4.2
12"	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Veg.	N	N	N	N	N	N	N*	N	N	N

SITE P 1981 — 20.32 cm. (8") Sample Core #

	1	2
S	6.0 5.5	6.4 6.4
6"– 12"	6.4 6.5	7.0 7.1
Veg.	Y	Y

SITE D 1964 — 2.54 cm. (1") Sample Core #

	1	2	3	4	5	6	7	8	9	10
S	4.2	3.8	3.8	3.8	3.8	3.8	3.8	4.2	3.8	3.8
6"	4.2	3.8	3.8	3.8	3.8	4.2	3.8	4.6	3.8	4.6
12"	5.2	3.8	4.2	3.8	4.2	4.6	3.8	4.6	3.8	4.6
Veg.	N	N	N	N	N	N	N	N	N	N

SITE D 1981 — 20.32 cm. (8") Sample Core #

	1	2
S	3.8 3.6	3.9 3.8
6"–	3.4 3.6	3.8 4.4
12"	3.6	4.2
Veg.	N	N

SITE G 1964 — 2.54 cm. (1") Sample Core #

	1	2	3	4	5	6	7	8	9	10
S	6.6	7.4	6.0	5.2	6.4	7.4	7.4	7.4	3.8	7.4
6"	5.2	6.0	3.8	4.6	4.6	7.4	5.6	6.0	4.2	7.4
12"	3.8	3.8	3.8	4.2	4.2	4.6	4.6	4.2	3.8	7.4
Veg.	Y	Y	Y	Y	Y	Y	N	Y	Y	Y

SITE G 1981 — 20.32 cm. (8") Sample Core #

	1	2
S	5.7 5.6	4.5 6.1
6"– 12"	6.2 6.2	6.4 6.5
Veg.	Y	Y

For reasons described in Schrock (15), the PCA's were performed on log-transformed data and 1.0 was added to all original values before transformation to avoid difficulty with zero values.

Correlations were extracted from the correlation matrices produced as an intermediate stage in the construction of the PCA's.

Results

Soil Acidity

The slick acidic surfaces observed on the research sites in 1964 were absent at sites by 1981. From Table 2 it is obvious that site P has become less acidic and is revegetating. Site D has remained acidic and barren. While two sample cores are less representative than ten, they nevertheless portray a consistent pattern of neutralization of soil except at site D.

The average pH at each site in 1964 and 1981 is placed on Figure 1 and demonstrates the variation within both acidic and calcareous banks.

The extent to which site pH has changed over 17 years at all mined sites together is illustrated in Figure 3. The variation in pH at each site in 1964 and 1981 is given

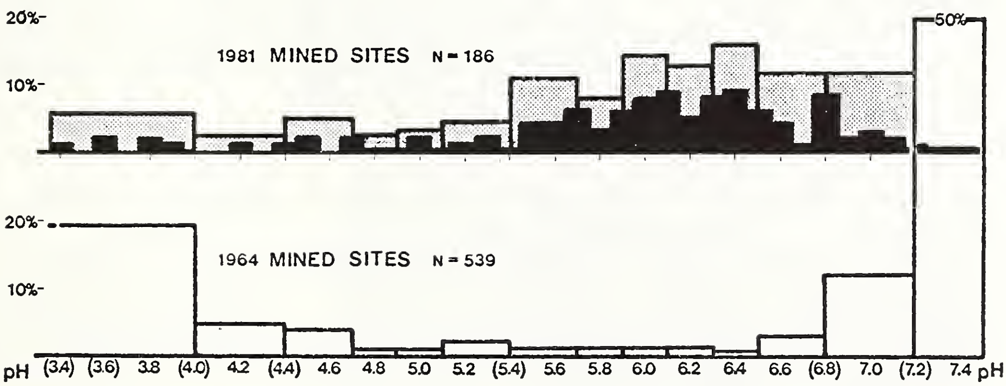

FIGURE 3. Frequency distribution of soil pH values at all mined sites in 1964 and 1981. Since the 1981 values were recorded to the nearest 0.1 pH unit (black) and the 1964 values were restricted to color indicators of varying resolution (white), the 1981 values are clustered into groups matching the 1964 indicator ranges for comparison (gray).

in Figure 4 by a circle with a radius of one standard deviation. These figures indicate which sites have moved well away from values held in 1964.

The common range for mineral soils in humid regions is 5.0 to 7.2 pH (3). Of three originally strongly acidic soils, only D has failed to move into this "normal" range. Of six calcareous soils, all have dropped to a pH well within this common range.

Soil Moisture and Infiltration

In 1964, Munsee noted that ". . . soil samples through which the water percolated most rapidly likewise show the greatest depth of penetration during the 7-day period." (Figure 5). The "slow" sites D, B, T, M . . . etc. were all of high clay content while the "fast" sites W, F, A, C . . . etc. were progressively higher in sand content (Figures 6-9).

Wetted-zone depth increased, though not uniformly, in 1981. Soil moisture-holding decreased in 1981. While water transmission is known to be low in spoils (6), this is the first direct evidence of substantial improvement over time.

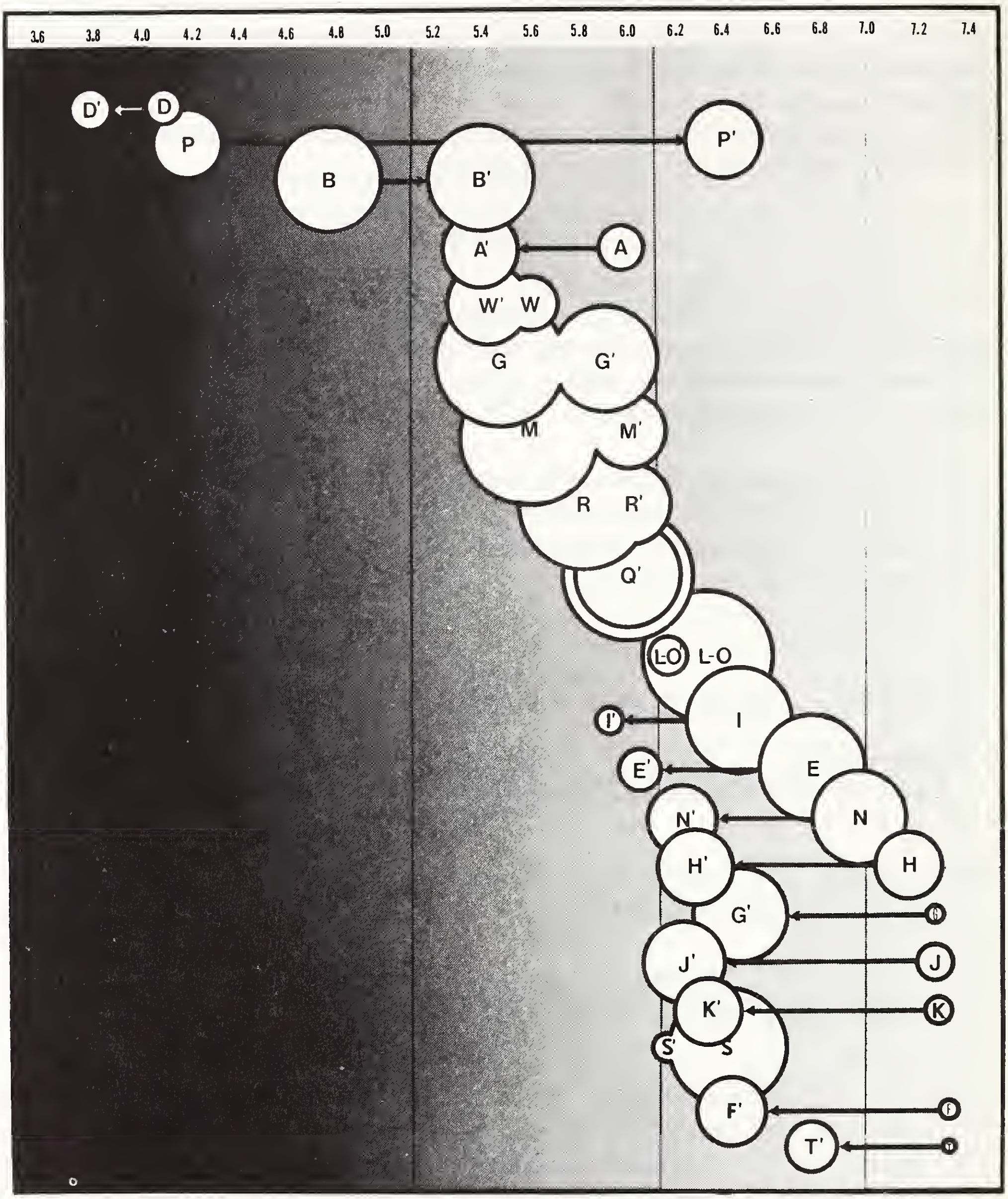

FIGURE 4. Changes in soil pH between 20 research sites in 1964 (W, A, B . . . T) and 1981 (W', A', B' . . . T'). Circles are centered on average pH value and the radius is drawn as one standard deviation.

Soil Texture

In contrast to other mining areas, stone and gravel did not appear dominant at these sites. No attempt was made to quantify coarse material either year, but it was noticeable that soil fines were well in excess of the discarded coarse material in most cases. In 1981, some larger aggregates were found to be very soft and readily crumbled in the preparations for soil tests. Occasional chunks of soft coal were picked up that could be crushed between fingers, and tiny black flecks of such material were evident in some of the soil infiltration columns.

In addition to the unmined site W, sites C and F were sandy enough to be noticeably different from other spoils in the field in 1964 and 1981. The high silt reading for site P (Figure 9) is extreme and would be questionable if it were not for corroborating

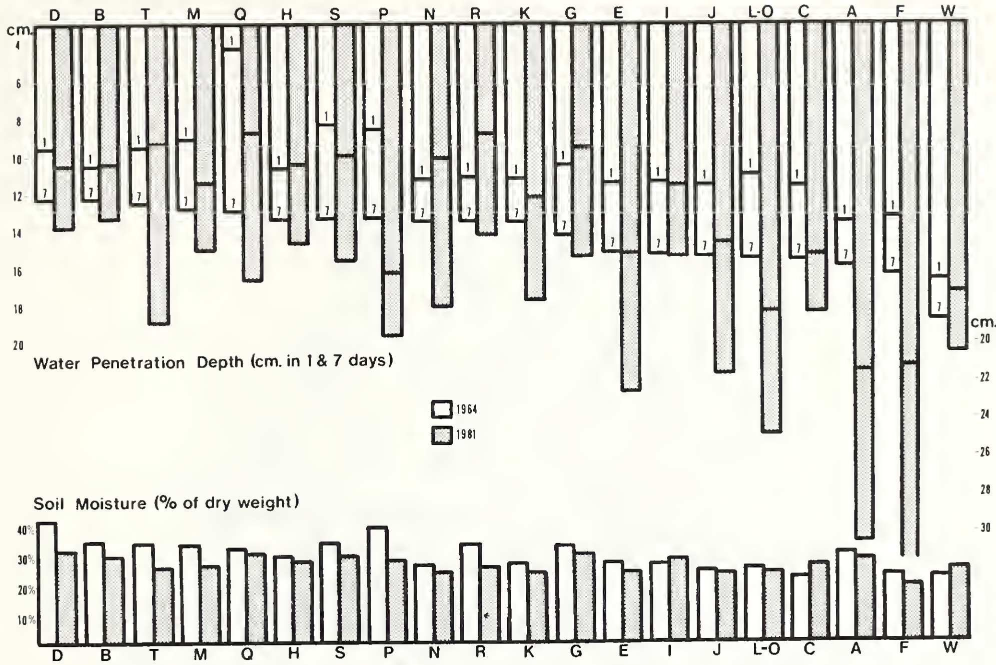

Figure 5. Changes in depth of water infiltration and changes in soil moisture at each research site in 1964 and 1981.

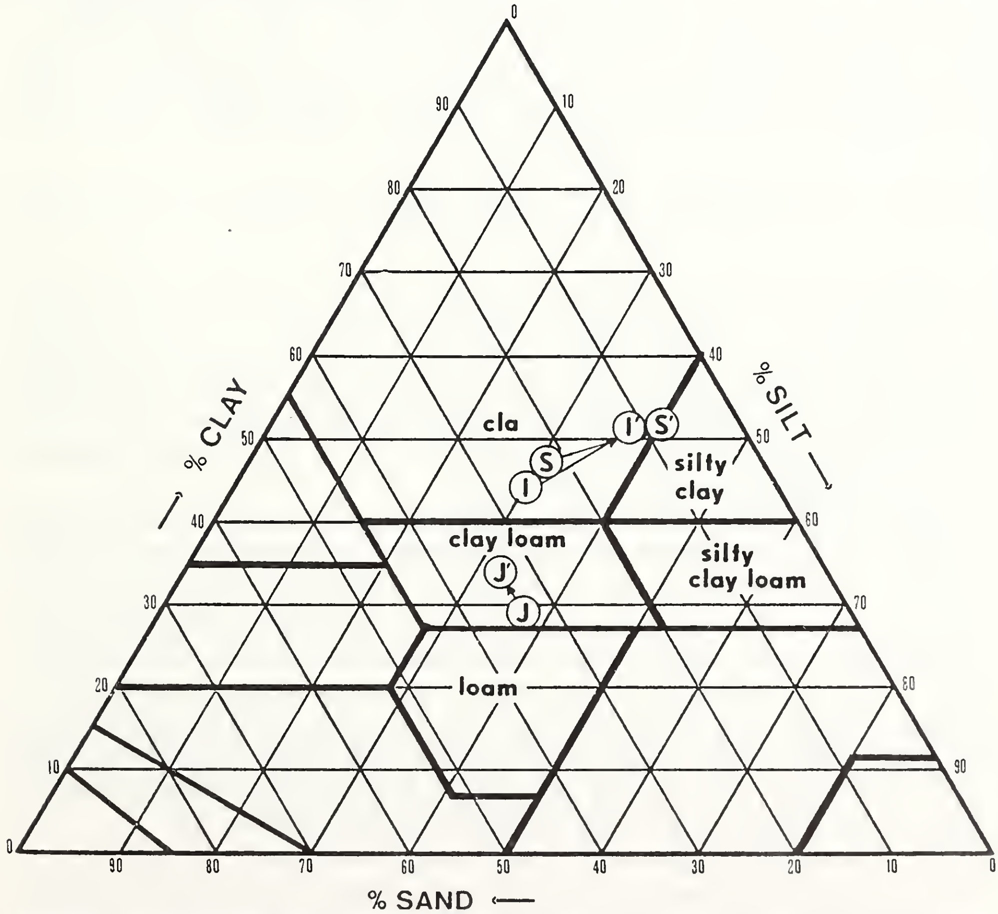

Figure 6. Soil textures at near-level ridge-top sites (less than 10% slope) measured in 1964 (I, J, S) and 1981 (I′, J′, S′).

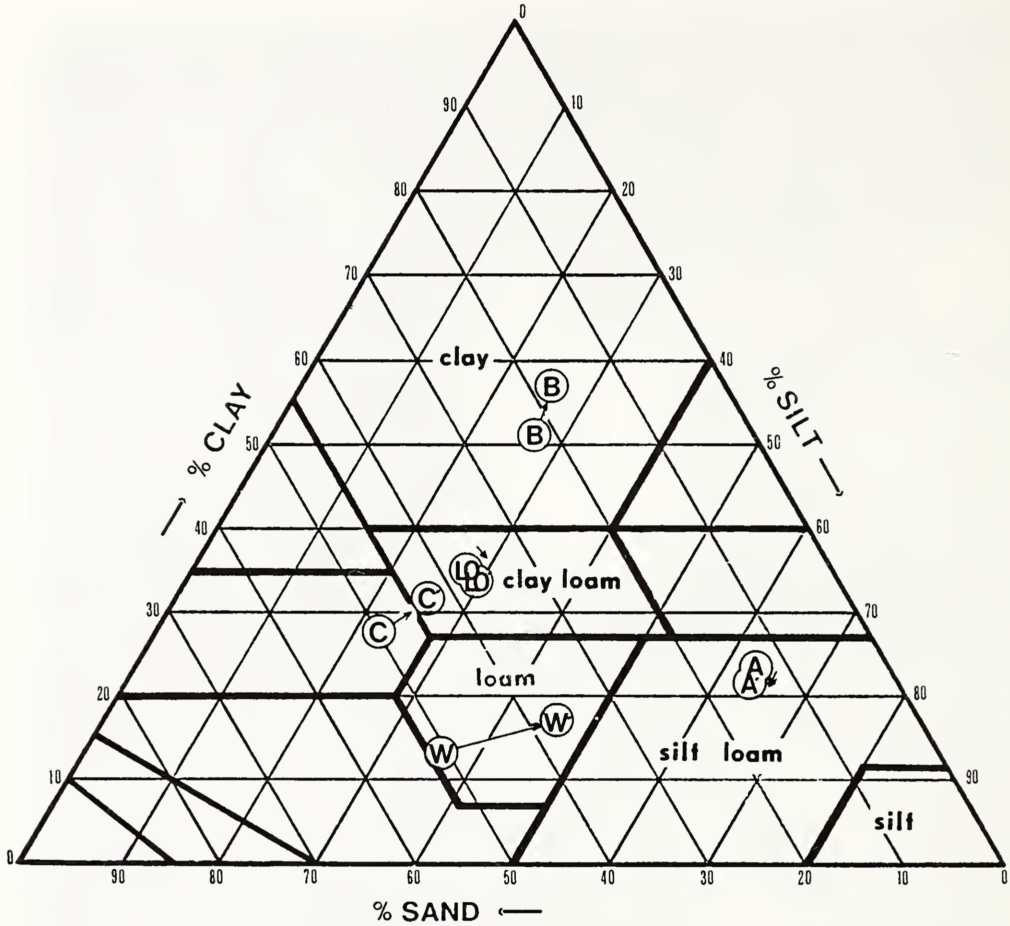

FIGURE 7. Soil textures at near-level sites (less than 10% slope) measured in 1964 (W, A, B, C, L-O) and 1981 (W′, A′, B′, C′, L-O′).

with a third. This becomes an "apples-and-oranges" problem in which we find ourselves asking if a similarity in vegetation between site B and C is more or less important than a similarity in soil texture between site B and C, for instance. To ask which sites are most similar without regard to some organism's response or other criteria, leaves the clustering by similarity dependent on an artificial weighting of one for each factor. The internodal distance and even the clustering order will be prejudiced by the factors chosen and this uniform weight for each factor.

Based on slope, soil silt and clay fractions, soil pH, moisture-holding capacity and maximum water penetration, percent bareground, exposure, slope, plant hits (out of 100 point drops) and basal areas of trees as architectural features, and daily and annual solar insolation, the sites do not cluster in a completely arbitrary manner in observations: "On the occasions that the pitfall traps were flooded in Site P the liquid contents of the trap bottles turned into a grey, viscous, colloidal suspension" (10). Pitfall samples from site P preserved in vials from the rainy weeks in 1964 had considerable silt despite several rinsings during extraction of insects. By 1981, site P has crossed the texture chart to reside with the clay banks (Figure 9). None of the flooded traps, including traps at site P, exhibited high amounts of silt in 1981.

General Site Characteristics

If two sites were identical in soil pH, texture, water capacity, and had similar trees and herbacious cover, we would consider them more closely related to each other than to a barren site with different soil properties. The task becomes more difficult

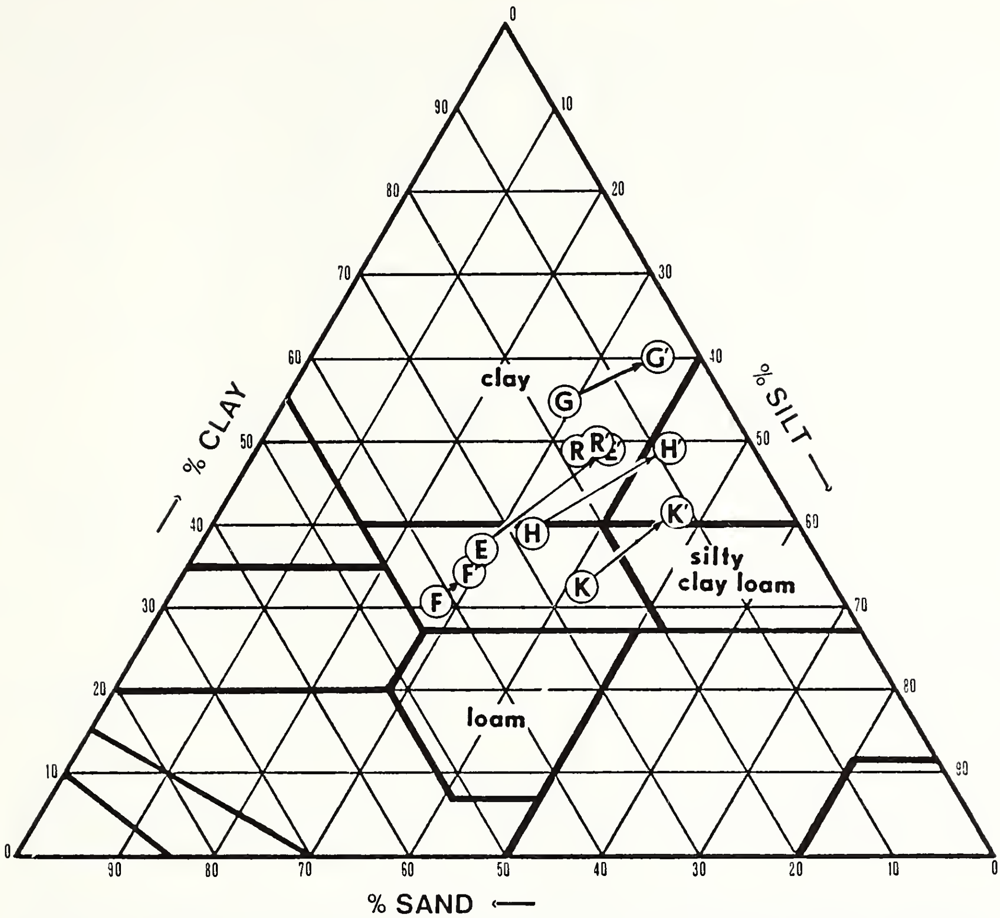

FIGURE 8. Soil textures at steep sites (greater than 50% slope) measured in 1964 (E, F, G, H, K, R) and 1981 (E', F', G', H', K', R').

when the first site shares some characteristics with the second site, other characteristics 1964 and these clusters hold similar patterns in 1981 (Figure 10). Since sites W and A cluster together, this lends some biological credence to the process. Sites C-I-M, J-S-Q-L-L-N-B, and G-D remain associated. Sites T and H have made major changes in associations and site K is unique in physical features in 1964 and even more so in 1981.

Correlations between selected site characteristics were remarkable for their consistency in sign between 1964 and 1981 (Figure 11). Strong correlations between some factors indicate that, while one may not directly cause changes in a second, both have a strong relationship to a "common environmental factor."

Principal Components Analysis

Variation from all of these soil factors is arrayed for the first three principal components (described below) in both years in Figures 12 and 13. Several characteristics are not totally independent. Silt and clay (plus sand) total unity. The clay fraction holds water and this water-holding ability prevents deeper soil penetration. Potential solar radiation is determined from tables involving slope as one of three factors. Nevertheless, each of these three factors contributed sufficient unique variation to be included in correlations with various arthropods discussed elsewhere (15).

When variation among sites' physical features is analyzed on the basis of twelve measured variables for 1964, the sites array as shown in Figure 12 with the first three factors explaining the greatest share of combined variation. Variation in factor 1 is composed of water capacity, maximum water penetration, bare ground, pH, plant hits

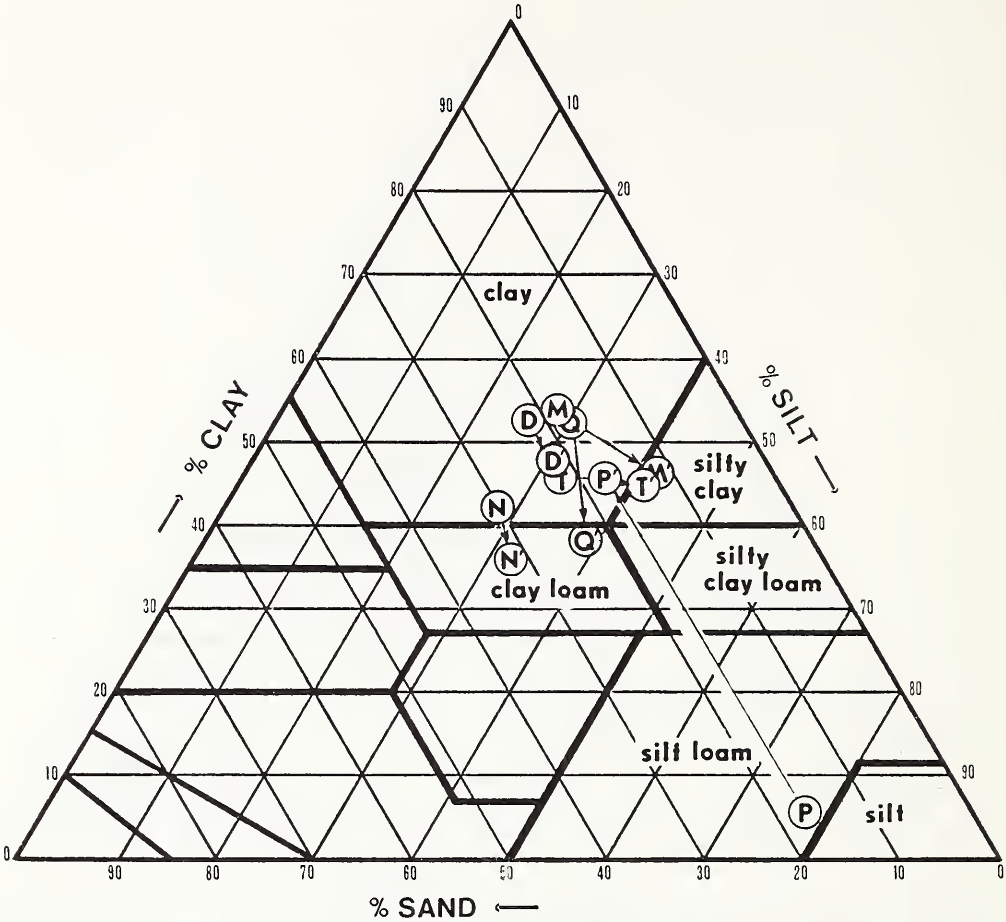

FIGURE 9. Soil textures at remaining sites measured in 1964 (D, M, N, P, Q) and 1981 (D′, M′, N′, P′, Q′). Note the drastic change at site P.

and tree basal area. Factor 2 is composed of soil texture, plant hits, tree basal area, maximum water penetration and pH. Factor 3 is composed of variation contributed from daily and annual insolation, slope and pH. Therefore, pH is the only characteristic to account for major variation on all three axes. The first three factors account for 72 percent of total site variation. Sites A and W are together far in the background while site P is near site D on factors 1 and 3 but distant on factor 2. Most of the spoilbanks except P float slightly in front of the factor 1x3 plane. By 1981 (Figure 13), site P has returned to the fold of strip mine sites. The strip mine sites have also tightened up, reflecting the decrease in extreme soil factor readings and fairly uniform increases in plants and trees. Nevertheless, roughly two clusters of strip mine sites remain: the B-M-S-Q-I-L-N-J-C tight cluster found loosely on the positive side of factor 3 in 1964, and the R-G-T-H-E-K cluster found on the negative side of factor 3 in 1964.

By 1981, the first three factors only account of 64 percent of the variation. Now pH, daily insolation and clay contribute to all three factors. Bare ground, slope, water penetration, plant hits and tree basal area contribute to factor 1. Factor 2 also includes variation in water capacity, maximum water penetration and slope. Factor 3 concentrates on plant hits, bare ground, exposure and tree basal area.

Conclusions

In discussing the present soil situation, it is useful to know what the original soil overlying the area was before stripmining in 1949-1951. The Soil Survey of Ver-

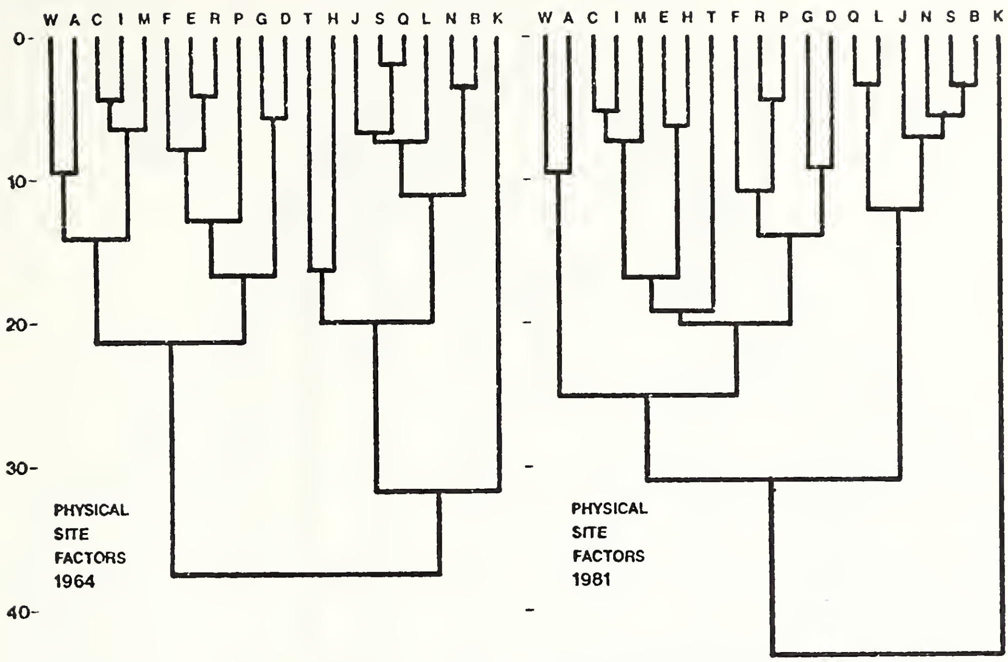

Figure 10. Dendograms clustering sites on basis of physical factors at each site in 1964 and 1981.

million County, Indiana (14), based on fieldwork completed from 1972 to 1975 describes the adjacent land as a mosaic of Hennepin loam on the steeper slopes and Russell silt loam on the flatter terrain. Their soil map outline superimposed on an aerial photo places sites W and A on these soil types respectively. These soil types projected by the Soil Survey are based on air photos, a necessarily sparse sampling program and knowledge of local soil genesis. The texture values of the mapped soils is confirmed

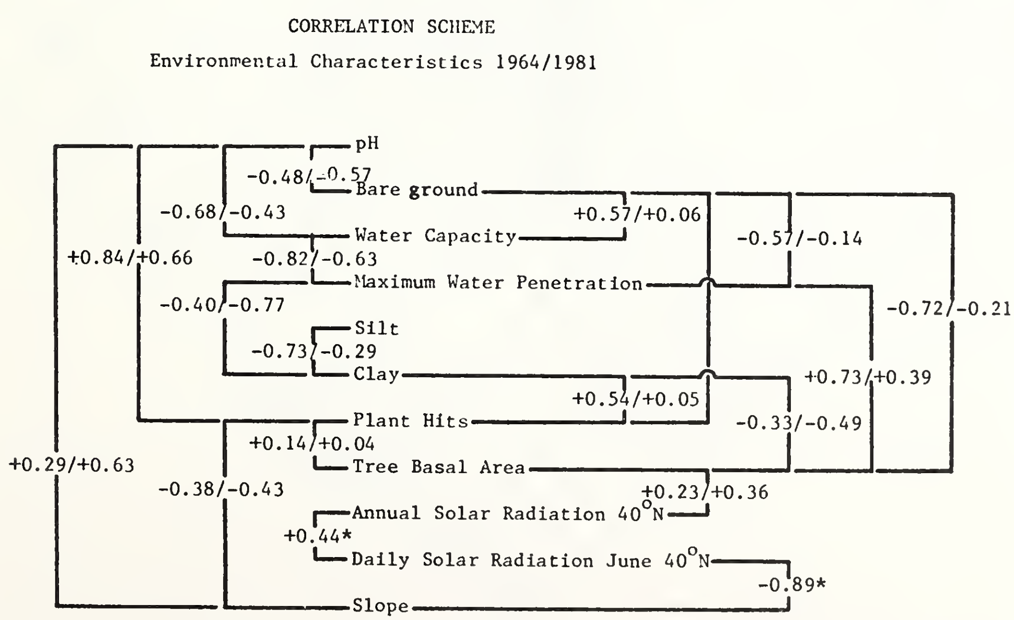

Figure 11. Correlations between selected characteristics of the research sites in 1964/1981. Note that the sign of correlation remains unchanged. Some values were considered unchanged between the two studies (*).

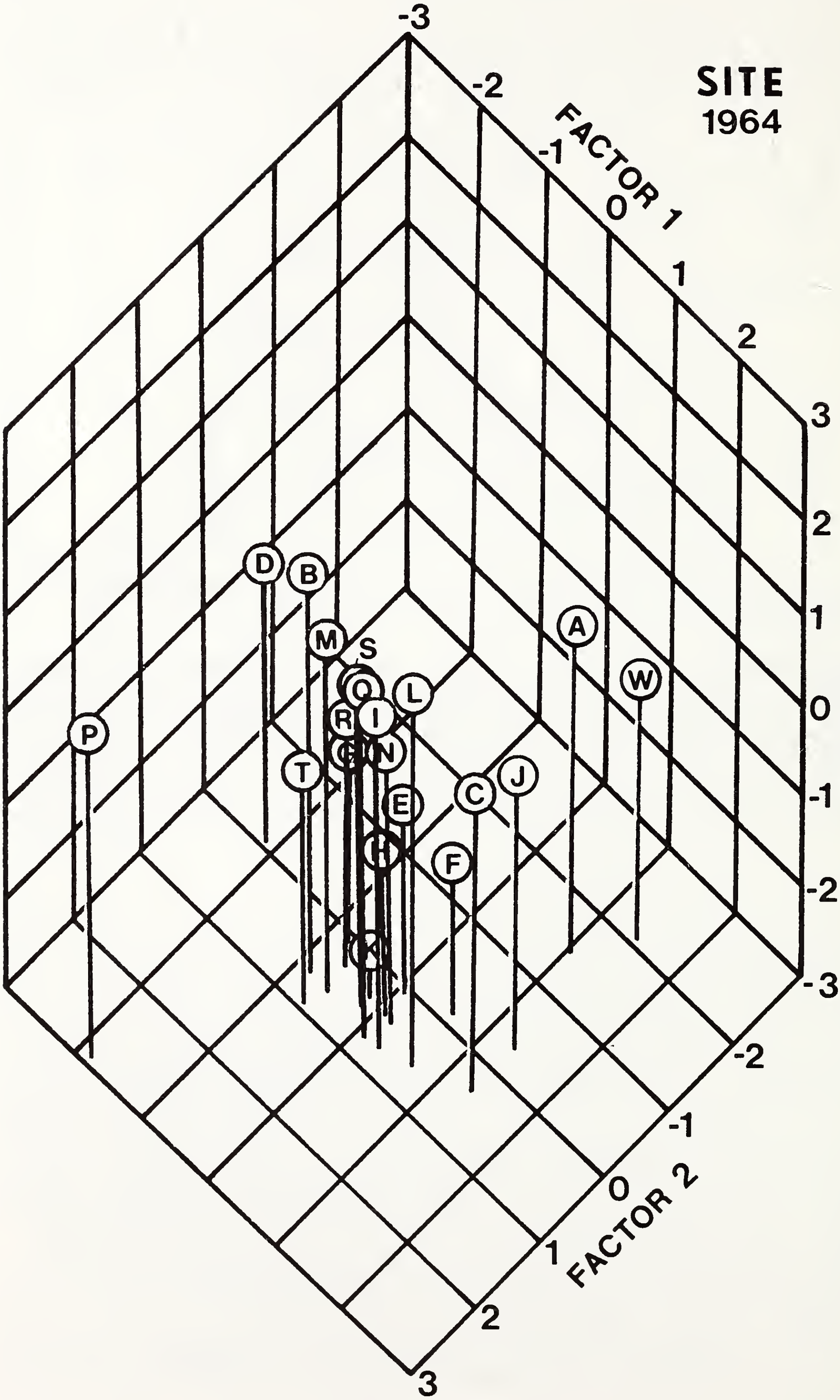

FIGURE 12. Principal components analysis of 1964 sites on physical site factors.

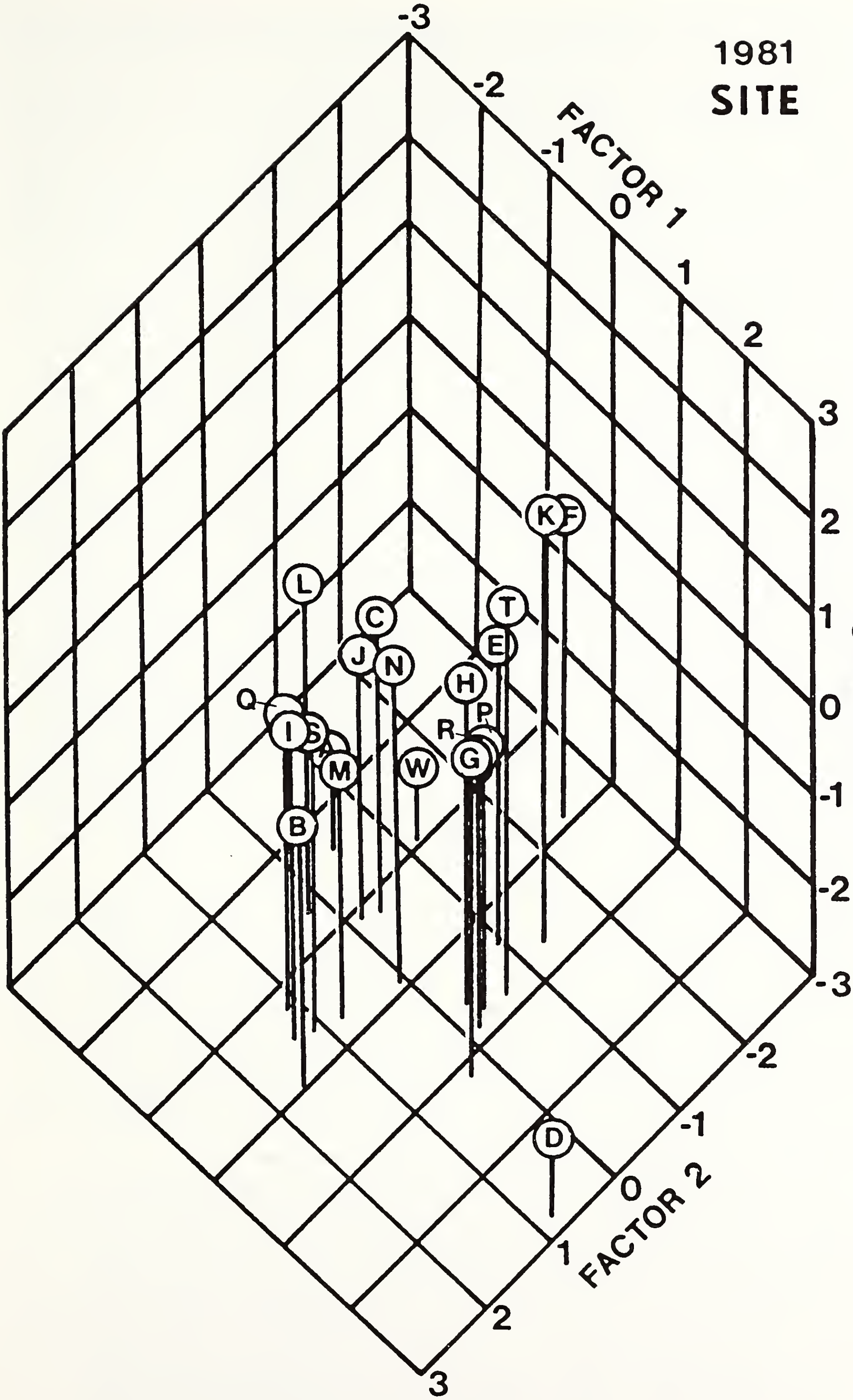

Figure 13. Principal components analysis of 1981 sites on physical site factors.

by both the 1964 and 1981 textures measured on sites W and A in this study. There is little reason not to believe that such soils covered the whole research area prior to mining.

After stripping, the unleveled spoilbanks are classified as Orthents and consist of variable amounts of ". . . loam glacial till, rock and shale fragments, and small fragments of clay and coal." (14) This is confirmed by the mining soil samples taken in this study. When deposited near the surface and subjected to weathering, the spoils undergo chemical reactions releasing an excess of H^+ ions (17). According to the laboratory work of VonDemfange and Warner (19), ". . . there is sufficient neutralizing potential in only three feet of spoil to neutralize the acid that is likely to be produced by the spoils." Yet, they acknowledge that more acid is initially produced than is neutralized by calcium and mangesium minerals in the spoilbank. This discrepancy is likely due to the oxidation rate of pyrite proceeding more rapidly than the slower neutralizing reactions. In this study, for the first time we follow specific sites and detect neutralization directly over time.

Soil acidity appears to be "evening out" and approaching a median pH between 5.8 and 6.2. This probably involves the leaching of calcareous banks and the depletion of sulfur compounds in acidic banks. This is suggested strongly by both Table 2 and Figure 4. Two enigmas appear in the latter figure however: site D becomes slightly more acidic and site P recovers with a dramatic shift twice that of any other site.

Site D is the only barren site in 1981, an impressive ridge over 60 feet high. In June of 1980 a half-buried iron reinforcement rod was found in the sediment at the base of this ridge. According to Munsee, that was one of the few rods left on site in 1964 and its original location was at the top of the bank. This provides one possible reason why site D remains acid and unrevegetated today. If a four-foot reinforcement rod, buried for much of its length in a clay-slate bank, has been undercut and washed to the base of the hill, there is grounds to believe that over 17 years, erosion has been sufficient to remove weathered material and expose fresh sulfur compounds. This could also prevent long-term rooting of perennials. Confirmation of this would require erosion pin techniques.

Soil at site P undergoes an unexpected rise in pH from 4.2 to 6.4 with a relatively small variance in each sample series. Site P also shows an equally phenomenal change in texture. Therefore it is valid to ask if we mislocated the site in 1981. However, site P is very distinct. It is the south face of a small ridge with outstanding small scale features. To the east is the flat basin of L-O; to the west the ridge bends and levels out and becomes lower swampy territory never covered in 1964. Site P in 1964 was more barren than site D. Yet in 1981 all of the area that could conceivably be site P is revegetating. This is a biological confirmation that site P has advanced and supports the measured changes in pH and texture. Site P in 1981 has to be on site P in 1964 and we believe the pH and texture values are real.

Is there anything unique about this site that might account for major shifts in soil features that presumably take centuries to change? Site P is unique in having a stagnant pool of water lapping at its base eight feet or so below the trapsites. This pool has been present since mining and according to general observations by Munsee, has risen perhaps six inches since 1964. This moisture undoubtedly accounts for species of moss and fungi present at site P. The constant presence of soil moisture could perhaps be a factor that exhausts the pyrite, either by permitting continuous oxidation or by improving conditions for bacteria that can live in the presence of sulfur compounds. Water percolation appears to be the main factor in removing sodium ions from the surface foot of spoils in reclaimed coal spoils in the Northern Great Plains (12). Deeper and more rapid penetration of water is attributed to enlarged root systems from revegetation. Although this is sodium (rather than sulfur) on a non-acid mine, the process suggests that leaching is accelerated on spoils once vegetation is established. Heterogeneity within each site was apparent, especially in 1964 (Table 2). Therefore, the lack of a high number of subsamples as recommended by Berg (1) is a valid criticism. Measurements of plant-available phosphorus and nitrogen, shown to be a critical factor on some spoils of this type (18), were not made.

The changes in soil factors described here are admittedly not beyond dispute. We could be more comfortable if a more extensive grid of cores were sampled, if these core sites were permanently marked, and if they were repeatedly sampled at perhaps five-year intervals. While such a study was not anticipated by Munsee in 1964 or possible in a faunistic study in 1981, we feel our data suggest rapid changes in some spoilbanks over time and provide a basis for further studies aimed at confirming this.

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