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THE VANADIUM CONTENT OF HAWAIIAN ISLAND SOILS

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INTRODUCTION

Vanadium is one of the normal constituents of living matter and appears in small quantities in plants. Its actual physiological role and importance, however, were undetermined until recently. Studies by Arnon and Wessel (1953) have yielded evidence that vanadium is essential for green algae. Arnon (1958) also found that the element played a role in photosynthesis in green algae. Although its essential nature has been established for the green algae only, vanadium may in time be proved an essential element for the higher plants.

The nature of the parent material is a major factor in determining the amount of the trace element that is present in the soil. Goldschmidt (1954) states that the bulk of the vanadium is concentrated in the magnetite and titano-magnetite of the igneous rocks. Basalts have generally been found to contain the highest concentrations of vanadium with lesser amounts in andesites and trachytes, the contents decreasing as the rocks become more silicic. The Hawaiian Islands have been built predominantly of basalts with small outcrops of andesites and trachytes. Therefore, it can be assumed that the soils of the Hawaiian Islands will contain vanadium.

The processes of weathering will determine the manner in which this vanadium is distributed throughout the soil profiles. A study of the patterns of distribution in the soil groupings by Cline, *et al.* (1955) was made to determine the influence of weathering on vanadium and its concentration.

Bertrand (1950) reviews the element extensively and lists the available literature to date. Subsequent to Bertrand's survey, studies dealing with vanadium have been limited to trace element determinations in soil profiles such as those by Butler (1954), Conner, *et al.* (1957), McKenzie (1957), and Tiller (1958). The vanadium content of arable soils as reported by these investigations ranges from 0 to a high of 500 ppm with an average of 100–200 ppm.

EXPERIMENTAL PROCEDURES

Description of Samples

Representative soil profiles of the Hawaiian Islands were analyzed for their vanadium content. Included among the profiles were soils ranging from the very youthful to the most highly weathered. Wherever possible, the parent material from which the soils developed was analyzed. Where concretionary material was found in the profiles, effort was made to analyze the concretions separately for their vanadium content.

Method of Analysis

The analytical method employed was a composite of methods outlined in Hillebrand, *et al.* (1953), Sandell (1936), and Sugawara, *et al.* (1953). The samples were prepared for vanadium analysis by following the sodium peroxide method from Hillebrand, *et al.*

The vanadium in the leachate was separated from chromium by using the method of Sugawara, *et al.* This was necessitated by the unusually high chromium content in Hawaiian soils. A suitable aliquot of the leachate was pipetted into a separatory funnel and acidified with 2 N sulfuric acid to the intermediate color of methyl orange. The solution was then swirled to liberate the carbon dioxide produced in the neutralization process and an excess of 2ml of the 2 N sulfuric acid was added. One ml of 5% malonic acid and 0.5 ml of 2.5% 8-hydroxyquinoline (dissolved in 1:8 acetic acid) solution were added to the acidified solution. The entire mixture was vigorously shaken and approximately 4 ml of a 4 N sodium acetate solution was added for the purpose of buffering the mixture at the pH at which the dark black-green vanadium quinolate compound was precipitated out. This compound was extracted with 3 ml of chloroform by vigorously shaking the sample and drawing off the chloroform layer containing the vanadium-quinolate into a platinum crucible. Three extractions with 8-hydroxyquinoline and chloroform were sufficient to remove all of the vanadium.

One gram of sodium carbonate was added to the united chloroform extract and left standing overnight to allow the chloroform to evaporate. The residue was heated slowly at first to destroy the organic matter and was finally fused by the flame of a full burner. The melt was digested with water and made to a volume not greater than 15 ml.

The vanadium content was determined by using the phosphotungstic acid method described by Sandell. The color of the solution was read using the 400 μ filter and compared with a standard curve.

EXPERIMENTAL RESULTS

Content of Vanadium in Some Hawaiian Rocks

The samples of rocks available for this study were few in number and are listed in table 1. The vanadium content of the rock samples was found to parallel the findings of Wager and Mitchell in their study of a suite of Hawaiian lavas (1953). The olivine basalt, the picrite basalt, and the melilite nephilene basalt were found to be high in vanadium, roughly averaging 300 ppm. The one sample of andesite analyzed contained 97 ppm of vanadium. In the soda trachyte, vanadium was not detectable by the method of analysis used.

Distribution of Vanadium in the Soil Profiles

The findings on vanadium distribution in soil profiles are contained in table 2. The Dark Magnesium Clays occur on alluvium that receives seepage water of

TABLE 1. The Vanadium Content of Some of the Rocks of the Hawaiian Islands

ROCK	LOCATION	V (PPM)
Picrite basalt, oceanite type	Kunia, Oahu	100
	Kunia, Oahu	255
Picrite basalt, ankaramite type	Waikolu Valley, Molokai	310
Olivine basalt	Mauna Loa, Hawaii, 1950	190
	Kapoho, Hawaii, 1955	415
Volcanic ash (partially weathered)	Salt Lake Crater, Oahu	215
Cinder	Round Top, Oahu	300
Melilite nepheline basalt	Moiliili Quarry, Oahu	280
Hawaiite	Haleakala, Maui	97
Trachyte	West Maui	Not detected

high magnesium content or on high olivine content basalts, where the dominating characteristic is the high exchangeable magnesium content of the soil. The Gray Hydromorphic soils are strongly influenced by an excess of water resulting from a high water table or from poor internal drainage. There is no horizonal differentiation in either of these soils, with the vanadium content remaining constant throughout the profiles.

The Red Desert soil, which has developed under arid conditions in the lowlands, is a soil weathered from shallow deposits of ash on lava. Although it is the least weathered zonal soil in this study, it is predominantly a 2:1 clay and amorphous material. In terms of elevation, the area in which the Reddish Prairie soil has been developed is above the lowland area with the Red Desert soil. This area is in a moderate rainfall zone and the Reddish Prairie soil has developed from ash to a soil composed predominantly of 2:1 clay, amorphous material, and organic matter. The Latosolic Brown Forest soil is a rapidly weathering intra-zonal soil developed from ash in a high rainfall area. Although this is a youthful soil, it must be considered a highly weathered soil because of its low silica sesquioxide ratio of about 0.3. There is a definite concentration of vanadium in the surface horizon with smaller amounts in the lower horizons. In the Red Desert and Reddish Prairie soils, the distribution was constant throughout the profiles.

The soils of the Low Humic Latosol Group have developed from lava in a dry to moderately humid climate and are the least weathered soils of the Latosolic Group. The concentration of vanadium was found to be constant throughout the profiles in the Molokai, Lahaina, and Wahiawa family soils from low rainfall areas. The Kohala family soils are from areas of higher rainfall and consequently are more highly weathered than the three families mentioned previously. These soils were found to have considerably higher vanadium concentrations. The vanadium distribution within the soil profiles of the Kahana and Kohala families from the island of Kauai indicates that the content of vanadium increased in the B_3 and B_4 horizons of the Kahana and the B_1 and B_2 of the Kohala soils. The increased concentration in the B horizons could reflect lithologic discontinuities in the soils.

The Humic Latosol Group has been subjected to more weathering than the Low Humic Latosols. The Hydrol Humic Latosol is the most highly leached soil, having developed in a continuous heavy rainfall area. The family divisions here have been based on the texture of the parent material, that is, on the basis of the soil having been developed on rock or volcanic ash. For example, of the four families studied in the Humic Latosol and the Hydrol Humic Latosol Groups, the Kaneohe family of the Humic Latosol has been developed from lava, whereas the remaining three soils have been developed from volcanic ash. The soil profiles showed a uniform distribution of vanadium.

In the Humic Ferruginous Latosol Group of highly weathered soils, vanadium stratification was found to be most pronounced. Iron and titanium oxides are concentrated in the surface horizons of these soils. Vanadium likewise was found to follow this stratification.

The amount of vanadium in the A horizons of the soils analyzed ranged from 190 ppm to 1520 ppm. The Dark Magnesium Clays and the Gray Hydromorphic clays averaged 300 ppm vanadium. The Red Desert and Reddish Prairie averaged 350 ppm vanadium. The Latosolic Brown Forest averaged 400 ppm, all concentrated in the surface horizons. The Molokai, Lahaina, and Wahiawa families of the Low Humic Latosol Group contained approximately 450 ppm of vanadium, with the Kahana containing 500 ppm and the Kohola averaging 800 ppm, the concentrations increasing gradually with weathering. The Humic Latosols averaged approximately 350 ppm vanadium and the Hydrol Humic Latosols averaged approximately 575 ppm. These soils cover our agriculturally important lands and the average vanadium content for the soils was approximately 450 ppm. In comparison with the vanadium content in other soils of the world as given in the available literature compiled by Swaine (1955), the Hawaiian soils contain slightly higher amounts of vanadium.

The highest vanadium concentrations were found in the Humic Ferruginous Latosol Group, where the content ranged from a low of 400 ppm to a high of 1600 ppm. In this Group, the concentration ratio of vanadium, to be discussed in the following section, was found to be high, but the amount of the element varied with the parent material of the individual soil profiles. The concentrations were highest in the heavy mineral horizons and lowest in the layer just above the parent material.

TABLE 2. The Vanadium Content of Typical Soil Profiles of the Hawaiian Islands

GREAT SOIL GROUP	SOIL FAMILY	LOCATION	AVERAGE RAINFALL (INCHES)	HORIZON	DEPTH (INCHES)	V (PPM)
Dark Magnesium Clay	Lualualei	Lualualei, Oahu	30	A	0–6	335
				B	6–12	295
				B	12–18	280
				C	18–24	290
		Lualualei, Oahu	30	A	0–3	No Sample
				A	3–10	290
				B	10–18	300
				B	18–24	300
				B	24–38	280
				B	38–51	320
				C	51+	280
Gray Hydromorphic	Kalihi	Kaloko, Oahu	26		0–4	280
					4–14	280
					14–22	305
					22–27	295
					27–40	295
					40+	280
	Kaloko	Honouliuli, Oahu	31		0–4	385
					4–14	385
					14–32	460
Red Desert	Kawaihae	Makena, Maui	20	A_1	0–4	370
				A_2	4–12	415
				B	12–18	310
				C	18–34	360
					Cinder	260
Reddish Prairie	Waimea	Haleakala Road, Maui	35	A_{1-1}	0–13	310
				A_{1-2}	13–26	370
				A_{1-3}	26–40	370
				B	40–64	320
				C	64–88	350
					Rock and Cinder	320
Latosolic Brown Forest	Hanipoe	Haleakala Road, Maui	54	A_1	0–4	360
				A_{1-2}	4–9	580
				B_1	9–12	310
				B_2	12–20	340
				B_3	20–36	330
				B_4	36–47	260
				C	47–71	295
					Cinder and Rock	155
	Olinda	Olinda, Maui	89	A_{1-1}	0–4	480
				A_{1-2}	4–12	190
				AB	12–26	170
				B	26–42	60
				B	42–55	70
				C	55–70	65
					Rock	65

(*Continued*)

TABLE 2. The Vanadium Content of Typical Soil Profiles of the Hawaiian Islands (*continued*)

GREAT SOIL GROUP	SOIL FAMILY	LOCATION	AVERAGE RAINFALL (INCHES)	HORIZON	DEPTH (INCHES)	V (PPM)
	Molokai	Kunia, Oahu	24	A	0–8	415
				B	8–24	410
				C	24–36	520
	Lahaina	Waialua, Oahu	35	A_1	0–6	440
				B_1	6–11	431
				B_2	11–18	350
				C	18–22	348
	Wahiawa	Poamoho, Oahu	40	A_1	0–10	320
				B_1	10–21	410
				B_2	21–42	450
				C	42+	535
Low Humic Latosol	Kahana	Anahole, Kauai	50	A_1	0–9	500
				B_1	9–18	500
				B_{2-1}	18–21	520
				B_{2-2}	21–28	540
				B_3	28–34	600
				B_4	34–52	680
				C	52+	480
	Kohala	Waimea, Oahu	50	A_{1-1}	0–1	740
				A_{1-2}	1–6	870
				AB	6–10	415
				B	10–24	460
				C or D	24+	450
		Lawai, Kauai	65	A_1	0–10	750
				A_2	10–15	830
				AB	15–20	860
				B_1	20–26	946
				B_2	26–44	930
Humic Latosol	Kaneohe	Kaneohe, Oahu	65	A	0–8	370
				B	8–24	350
				C	24–34	360
	Paauhau	Honokaa, Hawaii	64	A_{1-1}	0–7	290
				A_{1-2}	7–12	355
				B_1	12–20	390
				B_2	20–28	360

(*Continued*)

TABLE 2. The Vanadium Content of Typical Soil Profiles of the Hawaiian Islands (*continued*)

GREAT SOIL GROUP	SOIL FAMILY	LOCATION	AVERAGE RAINFALL (INCHES)	HORIZON	DEPTH (INCHES)	V (PPM)
Hydrol Humic Latosol	Hilo	Hilo, Hawaii	145	A	0–8	620
				B	8–40 (except dark layer)	620
				B_2	8–32 (dark layer)	620
	Akaka	Akaka Falls, Hawaii	225	A	0–12	540
				B	12–24	530
				B	24–32	510
				B	32–38 (dark layer)	530
				B	38–56	680
Humic Ferruginous Latosol	Mahana	Windward Lanai	34	A_1	0–6	720
				A_2	6–15	1020
				AB	15–21	830
				B_2	21–40	880
				B_3	40–48	770
				C	48+	560
	Naiwa	Kokee, Kauai	35	A_1	0–3	770
				A_2	3–5	1520
				A_3	5–11	1320
				B_1	11–13	1640
				B_2	13–27	880
				C	27+	510
		Wailuku, Maui	50	A_1	0–8	350
				A_2	8–14	545
				AB	14–20	410
				B	20–40	410
				C	40+	145
					partially weathered rockcore	<50
		Meyer Lake, Molokai	45	A	0–12	730
				B	12–20	735
				C	20–34	187
	Haiku	Lihue, Kauai	65	A_1	0–8	770
				A_2	8–14	780
				AB	14–22	770
				B_2	22–34	880
				B_3	34+	820

(*Continued*)

TABLE 2. The Vanadium Content of Typical Soil Profiles of the Hawaiian Islands (*continued*)

GREAT SOIL GROUP	SOIL FAMILY	LOCATION	AVERAGE RAINFALL (INCHES)	HORIZON	DEPTH (INCHES)	V (PPM)
Humic Ferruginous Latosol (continued)	Haiku (continued)	Haiku, Maui	70	A_1	0–8	1090
				A_2	8–14	1140
				AB	14–17	1020
				B_2	17–26	1020
				B_3	26–42	860
				C	42+	600
		Waipahee, Kauai	150	A_1	0–4	1000
				A_2	4–20	1330
				B_1	20–30	720
					(gibbsitic concretions)	400
				B_2	30+	880
					(gibbsitic concretions)	690

DISCUSSION OF RESULTS

Concentration Ratios in the Hawaiian Soils

Table 3 contains the concentration ratios of vanadium in the various samples. These ratios were obtained by dividing the average vanadium content of horizon A of each profile by the vanadium content of the parent material. It was not possible to obtain the actual parent materials on which the profiles were developed, except for the profiles of the Kawaihae, Waimea, Hanipoe, and Olinda soils, and the Naiwa soil from Wailuku, Maui. Where the actual parent materials were not collected, concentrations were derived by studying the volcanic flows underlying the areas from geologic maps of the Islands and assigning average concentrations to them, based upon tables from Wager and Mitchell (1953) and table 1 of this study. It should be further understood that since a single series ordinarily consists of different types of rocks, it was necessary to derive an average concentration for each series based on all the different flows in the series.

A concentration ratio of less than 1.0 indicates a removal of the element from the profile; conversely, a value greater than 1.0 indicates an accumulation of the element in the soil. The ratios in table 3 are all 1.0 or greater, except for the Kaloko family soil, showing that these soils are accumulating vanadium. The ratios also show that the concentration increases with weathering.

The nature of the parent material influences the total amount of vanadium in a soil profile. This is most clearly shown by a study of the Naiwa family soils. The vanadium content varies from 400 ppm in the Wailuku soil to 1600 ppm in the Kokee soil. This difference in the total content is due predominantly to parent material composition, since the other weathering factors were the same. The rock underlying the Wailuku soil contained <50 ppm of vanadium, while the parent rock of the Kokee soil contained 300 ppm. However, the concentration ratios in both instances were high. Thus, the concentration ratio eliminates the variable of the parent material and can be used as an index of the amount of weathering a soil has undergone.

There is a close correlation between the concentration ratios and the weathering sequences in the great soil groups. The Dark Magnesium Clays, Gray Hydromorphic, Red Desert, Reddish Prairie, and the Low Humic Latosol soils are the least weathered soils in this study. These soils have concentration ratios of 1.0 to 1.5, closely reflecting their weathering states. In the Kaloko family, a waterlogged clay, the concentration ratio was 0.84, the only sample with a ratio of less than 1.0. This downward movement of vanadium resulting in a ratio of less than 1.0 appears to be characteristic of gleyed soils. The Kohala family soils of the Low Humic Latosol are the high rainfall area soils in this group and they show a higher concentration ratio of 2.6.

The Humic Latosols and the Latosolic Brown Forest soils are from similar rainfall zones and have lost considerable amounts of SiO_2. The Latosolic Brown Forest soil, an intra-zonal soil developed on volcanic ash, is rapidly weathering and eventually will develop into a Humic Latosol or a Hydrol Humic Latosol. The concentration ratios for this group range from 3.0 to 4.5, increasing with rainfall. An exception is the Kaneohe family soil with a concentration of 1.0. Two possible explanations may be advanced for this discrepancy. The Kaneohe soil may not be properly classified within the Humic Latosol Group and perhaps should be included in a less weathered soil group. The texture of the parent material may also influence the rate of weathering. The Kaneohe soil was developed on basaltic flows, whereas the other three soils investigated were developed on ash deposits. The porous nature of the ash may have contributed to its more advanced state of weathering, whereas lava would be less susceptible to decomposition.

The Hydrol Humic Latosol has concentration ratios of 8.9 and 7.7, although it is in a highly leached state.

The soils in the Humic Ferruginous Latosol Group have concentration ratios ranging from 2.5 to >10. Mahana has a concentration ratio of 3.5. The ratios of the Naiwa family soils ranged from 5.0 to 10. The ratios for the Haiku family soils are 2.5, 3.5, and 4.0, increasing with rainfall. Although these concentration ratios are generally high, they nevertheless extend over a wide range. This latitude would seem to render the ratios useless as weathering indices. However, the authors are of the opinion that this is not necessarily so and will attempt to clarify this point in the following section.

TABLE 3. Concentration Ratio of Vanadium in Some of the Soils of the Hawaiian Islands

GREAT SOIL GROUP	SOIL FAMILY	SYMBOL	V IN HORIZON A / V IN PARENT MATERIAL	CONCENTRATION RATIO	RAINFALL (INCHES)
Dark Magnesium Clay	Lualualei	M	335/290	1.1	30
Gray Hydromorphic	Kalihi	H-2	280/280	1.0	26
	Kaloko	H-3	385/460	0.84	31
Red Desert	Kawaihae	RD	400/260	1.5	20
Reddish Prairie	Waimea	C-2	350/320	1.1	35
Latosolic Brown Forest	Hanipoe	F-1	450/155	2.9	54
	Olinda	F-4	300/65	4.6	89
Low Humic Latosol	Molokai	N-1	415/300	1.3	24
	Lahaina	N-2	440/300	1.4	35
	Wahiawa	N-3	320/300	1.0	40
	Kahana	N-4	500/300	1.6	50
	Kohala	N-5	800/300	2.6	50
			800/300	2.6	65
Humic Latosol	Kaneohe	A1D	370/300	1.2	65
	Paauhau	A-4	310/70	4.4	64
Hydrol Humic Latosol	Hilo	K-6	620/70	8.9	145
	Akaka	K-8	530/70	7.7	225

(Continued)

TABLE 3. Concentration Ratio of Vanadium in Some of the Soils of the Hawaiian Islands (*continued*)

GREAT SOIL GROUP	SOIL FAMILY	SYMBOL	V IN HORIZON A / V IN PARENT MATERIAL	CONCENTRATION RATIO	RAINFALL (INCHES)
Humic Ferruginous Latosol	Mahana	T-1	1000/300	3.3	34
	Naiwa (Kauai)	T-2	1500/300	5.0	35
	(Molokai)	T-2	730/70	10	45
	(Maui)	T-2	400/<50	>10	50
	Haiku (Lihue)	T-3	770/300	2.5	65
	(Maui)	T-3	1050/300	3.5	70
	(Waipahee)	T-3	1200/300	4.0	150

Relation of Concentration Ratio to Weathering

Figure 1 represents the vanadium concentration ratios plotted against rainfall, the principal weathering agent for tropical soils. The circles indicate the areas covered by a great soil group. The areas bounded by the solid line represent great soil groups developed from ash, and the areas bounded by the broken line represent soils developed from lava.

In the weathering sequences of the Latosolic Group, the Low Humic Latosol is a mature but least weathered soil. Under a more intensive weathering process, this soil might have developed into a Humic Ferruginous Latosol or a Humic Latosol. Under intermittent rainfall conditions it would probably have developed into a Humic Ferruginous Latosol and under continuously wet conditions into a Humic Latosol. On the graph, the Low Humic Latosols (N-1, N-2, N-3) of the lower rainfall area graduate into the Mahana family (T-1), then into the Naiwa family (T-2) of the Humic Ferruginous Latosols. All of these soils have developed in areas with alternating wet and dry seasons. However, the plots for the Haiku family (T-3) of the Humic Ferruginous Group, developed under continuously wet conditions, occupy an area contiguous to the Kohala family (N-5) of the Low Humic Latosol. More significantly, the Haiku (T-3) plots are found to be at nearly right angles to the plots for the Mahana and Naiwa families. Soil classificationists have voiced opinions that these soils should be reclassified within the Aluminous Ferruginous Latosol Group. The concentration ratios plotted

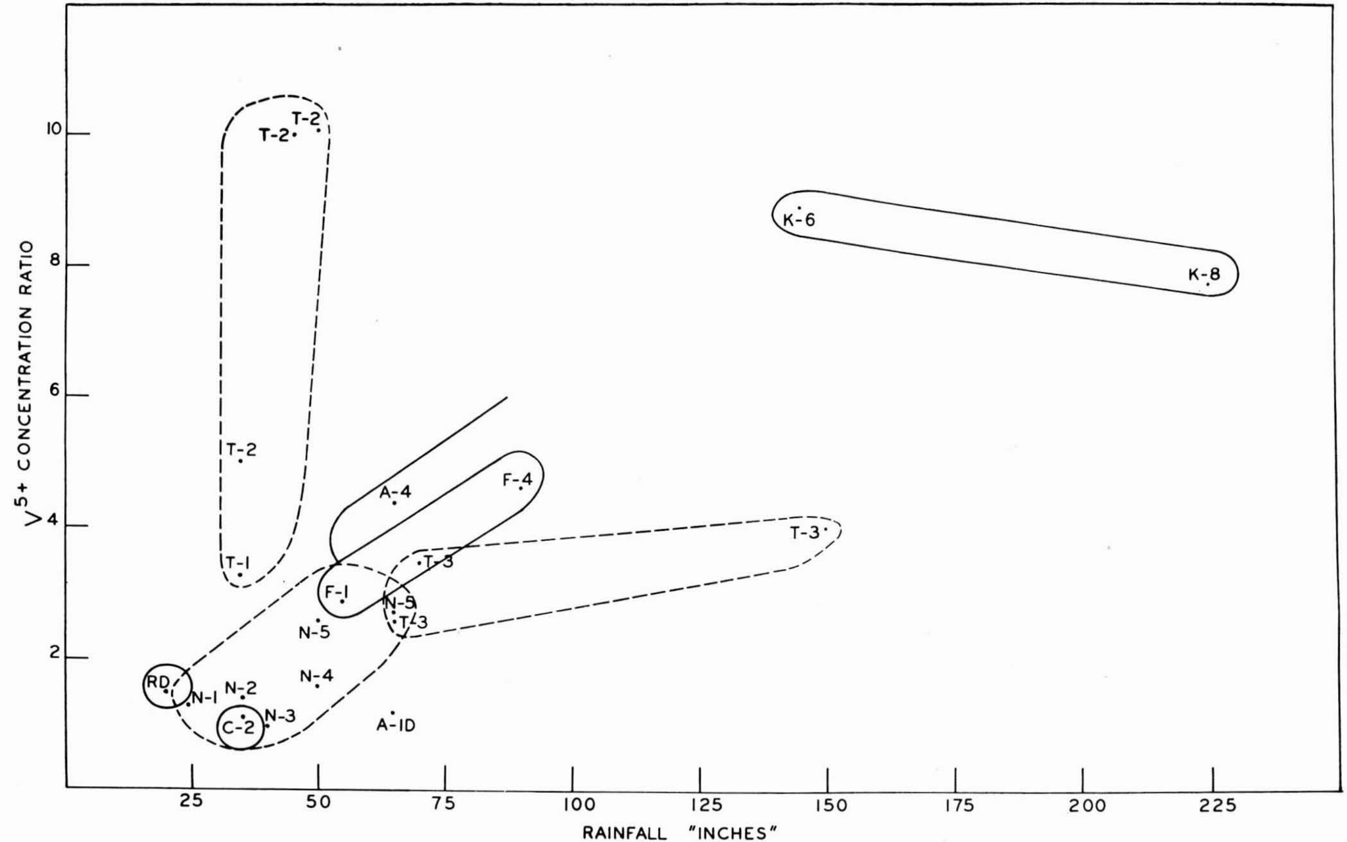

FIGURE 1. Relation between concentration ratio of V^{5+} and rainfall.

against weathering in figure 1 would tend to justify this proposed reclassification since these two families form two distinct soil groups on the graph.

As noted earlier, the families within the Humic Latosol have been separated on the basis of parent material texture. There are differences in the concentration ratios dependent on whether the soils were derived from lava or ash. Unfortunately, there was only one analysis available for each of these divisions. The Paauhau (A-4) developed on ash follows the correlation line set by the Reddish Prairie, Latosolic Brown Forest, and the Hydrol Humic Latosol, all developed on ash. The plots of the Humic Latosols will probably parallel the plots for the Latosolic Brown Forest and will occupy the same general area, grading into the Hydrol Humic Latosol. However, the Kaneohe (A1-D) developed on basalt falls within the Low Humic Latosol Group. Additional analyses of soils developed on lava which would make available more plots on the graph may show that this particular Kaneohe soil is either misclassified or that the area occupied by the Humic Latosols developed from lava may parallel the area occupied by the Humic Latosols developed from ash, but at a lower concentration level. This area would probably be beneath that occupied by the Aluminous Ferruginous Group (T-3).

In the Hawaiian Islands where the soil-forming process is normally latosolization, vanadium accumulates in the soil profile. Even in the Hydrol Humic Latosol, a porous soil leached by rainfall up to 225 inches, annually, vanadium has remained in the soil profile. The concentration ratios derived in this study may be useful as weathering indices for soils. In the samples analyzed and plotted against rainfall, there are indications that the concentration ratios will closely parallel the natural grouping of the soils.

Vanadium Concentration as an Indicator of Lithologic Discontinuity

Since vanadium is a cumulative element in the Hawaiian soils, an unusual decline or increase rather than a gradual change in the vanadium content from one horizon to another within the soil profile probably indicates the presence of a lithologic discontinuity in most instances. Table 2 contains three examples of probable discontinuities. The vanadium content in the Olinda family soil declines sharply at the 26-inch horizon, whereas there is only a gradual decline in the 0- to 26-inch horizon. The marked difference in the vanadium level between the A and B horizons would appear to preclude the possibility that the soil developed from the same parent material. The Olinda family is classed as an ash soil but this characteristic would indicate that the soil below the 26-inch horizon probably developed from rock.

The other two examples are the Kahana and Kohala family soils from Kauai. The lower B horizons show higher vanadium contents than the surface horizons. The higher concentration of the element in the B horizons probably indicates that this horizon was at one time a surface soil but that it was later covered by a lava flow which in turn has weathered into the present surface soil. The foregoing examples all illustrate the possibility of detecting lithologic discontinuities by examining the vanadium content of the soil profiles developed by latosolization.

Relation of Vanadium Content with Titanium

Sherman, *et al.* (1948, 1955) have done total analyses of some of the Humic Ferruginous Latosol soils used in this study. The results for vanadium were compared with their results for the major elements. There was a close correlation between the vanadium and titanium contents rather than the expected correlation between vanadium and iron. The major source of vanadium is the titanomagnetite in the parent rock. Since these soils show high residual concentrations of titano-maghemite, ilmenite, ferro-ilmenite, pseudobrookite, hematite, and anatase, it may be reasonable to assume that the bulk of the vanadium in the heavy mineral layers is residual vanadium. Table 4 lists the content of iron, titanium, and vanadium in some of the Humic Ferruginous Latosols.

The concentration of vanadium was fairly constant throughout the profiles of the Humic Latosols and the Hydrol Humic Latosols developed in continuously wet areas. There were little or no horizonal differentiations or stratifications to be seen in these profiles, but the concentration ratios indicate that there has been accumulation of vanadium. A Hilo family soil was separated into a gibbsitic fraction and its residual dark portion. The analysis of the gibbsitic portion showed 260 ppm vanadium and the dark portion showed 470 ppm. This indicates that vanadium is present in the gibbsitic portion, although the greater portion of the element remains with the non-gibbsitic portion of the soil. Vanadium may be a residual mineral, but it is also possible that in these highly leached profiles, it was mobilized and then fixed by the hydroxides of aluminum and iron and the organic matter which are the major components of these soils.

SUMMARY

The vanadium contents in the surface horizons of the Hawaiian soils range from 190 ppm to a high of 1520 ppm, with an average of 450 ppm. The very high concentrations are confined to the Humic Ferruginous Latosol Group. Thus, the vanadium contents of the Hawaiian soils are higher than those of other arable soils reported in the available literature.

The amount of vanadium in the soil is influenced by the amount found in the parent material but the concentration of the element is more clearly a reflection of the weathering processes. In the Hawaiian Islands, where the major soil-forming process is latosolization, vanadium accumulates in the soil profiles. This characteristic may be used to advantage to find lithologic discontinuities in soil profiles. The concentration ratios derived in this study reflected the weathering state of the soils. When these ratios were plotted against rainfall they fell into the natural soil grouping used by soil classificationists.

A correlation between the concentration of vanadium and titanium was observed in the Humic Ferruginous Latosol Group.

Table 4. Comparison of V (ppm), TiO_2(%) and Fe_2O_3(%) of Some of the Humic Ferruginous Latosol Soils

FAMILY	LOCATION	HORIZON	V (PPM)	TiO_2 (%)	Fe_2O_3 (%)
Mahana	Lanai	0–6	720	8.00	33.60
		6–15	1020	10.80	45.00
		15–21	830	8.18	42.52
		21–40	880	8.33	45.27
		40–48	770	5.16	35.16
Naiwa	Wailuku, Maui	0–8	350	7.68	35.52
		8–14	545	10.68	48.72
		14–20	410	6.68	22.32
		20–40	410	5.36	29.84
		40+	145	2.08	14.32
	Kokee, Kauai	0–3	770	19.37	38.20
		3–5	1520	24.69	48.50
		5–11	1320	25.02	47.50
		11–13	1640	9.43	57.23
		13–27	880	7.24	58.50
		27+	510	3.32	35.42
	Meyer Lake, Molokai	0–2	730	19.22	45.98
		12–20	735	19.56	41.64
		20–34	187	9.20	6.60
Haiku	Haiku, Maui	0–8	1090	17.36	43.24
		8–14	1140	18.92	48.08
		14–17	1020	12.16	46.84
		17–26	1020	10.24	47.36
		26–42	860	8.88	42.54
		42+	600	6.68	28.72

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