The general appearance of the flattened garnets is shown in figure 1. They range in size from a few hundredths of an inch to a half inch in diameter, although the latter size is unusual. Most of them do not exceed a quarter of an inch in the largest dimension. They are all thin and none of those examined exceeded an eighth of an inch in thickness. Many of the flattened garnets show rounded edges, but some of them have fairly sharp ones. Examination of these sharp-edged crystals and some of the better formed ones with rounded edges suggests that they can be separated into two groups derived from the familiar isometric crystal forms, the rhombic dodecahedron and the trapezohedron (icosatetrahedron). A few specimens may be combinations of these forms. The clinographic projection of the equant-faced rhombic dodecahedron is shown in figure *2. 1.* The rhombic dodecahedron has 12 faces, each face a rhombus. The Miller indices of this form are (110). The reader will quickly realize, however, that crystals in nature frequently do not have all faces equally developed; that is, all faces will not be equal in size. It must be remembered that Steno's law of the constancy of interfacial angles is not concerned with the area of faces. As long as similar angles are equal, faces may vary greatly in area and crystals may appear distorted and yet satisfy the requirements of symmetry of form. Figure *2. 2.* was derived from figure *2. 1.* by increasing the size of two faces and reducing the others by moving the crystal edges parallel to themselves. However, most of the crystals are not so rhombic-outlined as shown in figure *2. 2.* and some of them appear to be six-sided. This type can be made by modifying figure *2. 2.* in the manner mentioned above. In this way the small face at the bottom of the figure and the one opposite to it can be moved parallel to themselves and the large flat faces will present a six-sided appearance, as shown in figure *2. 3.* A clinographic projection of the trapezohedron (211) is shown in figure *2. 4.* Figures *2. 5.* and *6.* show modifications of the equant-faced form by flattening the crystal.

These garnets are apparently slightly later than the muscovite host. They seem, in the case of the smaller individuals, to lie between the cleavage plates, but the larger ones and many of the smaller crystals when torn from their host leave well-defined holes. The garnets grew under restriction and their constituent elements were able to develop the usual internal arrangement, but the exterior form was greatly modified. Two parallel faces developed to a relatively large size and the remaining ones were unable to keep pace due to the influence exerted by the muscovite upon the growth of the garnets in directions other than those parallel to the cleavage direction of the mica.

It seems evident that these minerals that developed in the cleavage planes of the mica were not the result of primary crystallization from a magam, but represent secondary processes. This is in accord with the conclusions of Schaller, Hess, Landes, and others as to the importance of secondary hydrothermal processes in the paragenesis of pegmatites.

THE CALCIUM ANTAGONISM IN SOIL AND OAK WOOD

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CHAPTER I

INTRODUCTION

The antagonism existing between the components of a soil and the constituents of plants growing on the soil has been a subject of study by many investigators. Egorav[1] has shown that an antagonism exists between the calcium in the soil and the phosphates taken up by the plant. The greater the per cent of calcium in the soil, the less the amount of phosphates assimilated. He further showed that an increase in the amount of carbon dioxide in the soil tends to decrease the availability of the phosphate.

Mann[2] has studied the availability of manganese and iron as affected by the application of calcium carbonate and magnesium carbonate to the soil. For his studies he used soy beans grown in pots to which calcium carbonate and magnesium carbonate had been added in varying but known amounts. He found that, as the calcium carbonate in the soil was increased, there was a corresponding decrease in the amount of manganese taken up by the plant. His data[3] further show that there was, in general, a decrease in the iron in the plant with increase of calcium carbonate added as long as the p_H of the soil was below seven. He also shows that the p_H of a soil very largely depends on its calcium content.

The conditions governing the availability of iron have been studied by Gile and Carrero,[4] Jones and Shive,[5] and Carr and Brewer.[6] Willis and Carrero[7] have shown that the amount of water-soluble iron in the soil is no certain determinant of the amount of iron assimilated by the plant. Hopkins and Mann[8] suggest that iron can be taken up only in the ionized form.

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[1]Egorav, M. A. 1926. Lime and Phosphoric Acid in Soil. *Trans. Sci. Inst. Fertilisers (Moscow)*, 34: 37-45.

[2]Mann, H. B. 1930. Availability of Manganese and Iron as Affected by the Application of Calcium Carbonate and Magnesium Carbonate to the Soil. *Soil Science*, 30: 117-141.

[3]Mann, *Ibid.*, Table I.

[4]Gile, P. L., and J. O. Carrero. 1916. Assimilation of Iron by Rice from Certain Nutrient Solutions. *Journal of Agricultural Research*, 7: 503-528.

[5]Jones, L. H., and J. W. Shive. 1921. Effect of Ammonium Sulfate upon Plants in Nutrient Solutions Supplied with Ferric Phosphate and Ferrous Sulphate as Sources of Iron. *Journal of Agricultural Research*, 21: 701-728.

[6]Carr, R. H., and P. H. Brewer. 1923. Manganese, Aluminum, and Iron Ratio As Related to Soil Toxicity. *Journal of Industrial and Engineering Chemistry*, 15: 634.

[7]Willis, L. G., and J. O. Carrero. 1923. Influence of Some Nitrogen Fertilizers on the Development of Chlorosis in Rice. *Journal of Agricultural Research*, 24: 621-640.

[8]Hopkins, E. F., and F. B. Mann. 1917. Iron Requirements for Chlorella. *Botanical Gazette*, 84: 407-427.

Leroux and Leroux[9] investigated the distribution of iron in plants. They found that the proportion of iron in the ash of different plants was variable, ranging from 0.10% to 2.97%. Iron is unequally distributed in different plant organs. In herbaceous plants the ash of the roots, and after the latter, the ash of the flowers, was found to be particularly rich in iron. In woody plants the ash of the leaves regularly held the most iron. The ash of the stems of all plants was richest in calcium.

Ingalls and Shive[10] have shown that the total iron carried in the tissue fluids of a plant varies directly with changes in p_H of the fluids and that the p_H varies directly with the change in light intensity from day to night.

Eckstein and Jacob[11] have shown a pronounced antagonism to exist between the potash in the soil and the iron in the plant. They suggest the analysis of the plant as a simple and easy method of diagnosing the fertilizer needs of the soil. And Hoffer[12] has outlined in detail a simple method for making such a diagnosis.

The effect of the calcium content of the soil on the calcium content of plants growing on the soil has received some attention from investigators. Bryan[13] has made a study of the relation of soil calcium to the calcium in oats and wheat. The calcium content of oats varies with that of the soil, but variations in the quantity of soil calcium had no effect on the amount of calcium in the wheat. He explains this with the statement that the power of the wheat plant to assimilate calcium is very small.

The calcium content of timothy and red clover increases with the calcium content of the underlying soil.[14] Brown[15] has investigated the relation between the mineral constitution of apples and the soil on which they are grown and found that the percentage of potash varies directly with the amount of potash in the soil. She further found that there are strong indications that a similar relationship holds for phosphate, magnesia, and lime.

[9]Leroux, L., and D. Leroux. 1923. The Distribution of Iron in Plants. *Review of General Botany*, 25: 24-33.

[10]Ingalls, R. A., and J. W. Shive. 1931. Relation of Hydrogen Ion Concentration of Tissue Fluids to the Distribution of Iron in Plants. *Plant Physiology*, 6: 103-125.

[11]Eckstein, O., and A. Jacob 1929. Der Kali-Eisen-Antagonisimus in der Pflanze als Grundlage einer Methode zur Festellung des Kaliberdurfnisses der Boden. *Zeitschrift fur Pflanzenernahrung, Dungung, und Bodenkunde.* Vertag Chemie, Berlin.

[12]Hoffer, G. N. 1926. Testing Cornstalks Chemically to Aid in Determining Their Plant Food Needs. Indiana Agricultural Experiment Station, *Bulletin*, 298.

[13]Bryan, O. C. 1923. The Effect of Different Reactions on the Growth and Calcium Content of Oats and Wheat. *Soil Science*, 15: 375-381.

[14]Pugsley, L. I., and R. R. McKibbin. 1931. Calcium Relationships of Forage Crops. *Canadian Journal of Research*, 4: 3951.

[15]Brown, Janet W. 1929. The Relation between the Mineral Constitution of Apples and the Soil on Which They Are Grown. *Ann. Botany*, 43: 817-831.

A study of the effect of sodium chloride and calcium chloride in the soil upon the composition of young orange trees has been made by Reed and Haas.[16] When calcium is lacking in the soil the leaves, shoots, and rootlets of orange trees contain very little calcium. The calcium in the trunk of the tree decreases with decreasing soil calcium, but the decrease is not as rapid as the decrease in the leaves and other parts. They further found that the magnesium content of the trunk was greater in cases where the calcium of the trunk was low.

These studies lead to the conclusion that, in the case of many plants, the calcium content of the plant varies directly with the calcium content of the soil in which the plant grows and, possibly, in case of calcium deficiency in the soil the plant will replace the calcium with some other metal.

If antagonisms exist between calcium and phosphate, calcium and manganese, carbon dioxide and phosphate, and potassium and iron, it is quite possible that other antagonisms also exist. One of these possibilities is an antagonism between the calcium in the soil and the iron in the plant. Some of the data given by the investigators noted above seem to suggest that, possibly, such an antagonism exists. Other figures given would indicate that they found no specific relation between the soil calcium and the plant iron. In practically all cases either the number of tests made was so small or the conditions under which they were made were so modified that any relation that might exist in nature would, probably, not be evident. Mann used artificially limed soil in which the ratio of available calcium to total calcium, probably, was quite different from that existing in nature. Eckstein and Jacob used the hay grown on four small plots of ground in which conditions were changed from the natural by artificial fertilization. Hoffer modified natural conditions by adding calcium carbonate and superphosphate or potash.

In order to determine whether any relation exists between the calcium in soil and the iron in plants this study was undertaken. If such relationship exists, is it affected by the type of soil? If such a relation appears to exist, may it not rather be an influence of the p_H of soil in which lime is likely to be a factor? Following this idea further, is the iron content of a plant affected either by the organic matter in the soil or by the iron content of the soil?

Thus a number of investigators have established the fact that antagonisms exist between the components of a soil and the constituents of plants growing on it. Some of these antagonisms are: calcium and phosphate, carbon dioxide and phosphate, and manganese and iron.

The effect of the amount of soil calcium on the calcium content of certain plants has also been studied. In most of these plants the

[16]Reed, H. S., and R. C. Haas. 1923. Effect of Sodium Chloride and Calcium Chloride Upon the Growth and Composition of Young Orange Trees. *California Agricultural Experiment Station, Technical Paper*, No. 4.

calcium varies directly with the soil calcium and in cases of a calcium deficiency the plant may substitute some other metal for the calcium.

The distribution of iron in a plant has also received attention.

This study was made to determine what relationship, if any, exists between the pH, the organic matter, the iron, and the calcium of a soil and the iron in a plant growing in the soil.