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Report for 1960

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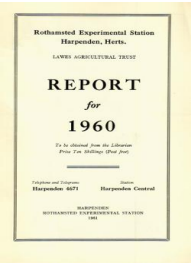
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Pedology Department

A. Muir

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PEDOLOGY DEPARTMENT

A. Muir

R. Greene-Kelly attended the 3rd Surface Activity Congress at Cologne, the 9th National Clay Conference at Purdue University and the autumn meeting of the Swedish Society for Clay Research at Stockholm. The last two were attended by invitation of the societies concerned. G. Brown and J. H. Rayner attended the International Crystallographic Congress in Cambridge.

A. H. Weir and Ng Siew Kee were awarded the degree of Ph.D. by London University.

Dr. M. Covadonga Rodriguez Pascual of the Instituto de Edafologia y Fisiologia Vegetal, Granada, is working with R. Greene-Kelly on the specific surface of soils. Various other workers spent short periods in the department learning special techniques.

Rock Weathering and Soil Formation

The mineralogical and micromorphological studies of red and yellow latosolic soils from Mount Zomba, Nyasaland, have been substantially completed. These soils belong to the group of " high-altitude soils " in Nyasaland (Young, 1960, *Preliminary soil map of Nyasaland*. Government Printer, Zomba), the main characteristics of which are dark-brown to black top-soils of high humus content overlying yellowish red, fine-textured but friable, strongly acid subsoils of moderate thickness on granite and syenite. Such soils occur at elevations of 5,000–9,000 feet under a wet climate, and are also extensive on Nyika plateau, High Vipja and the Mlanje mountains. Gibbsite, the dominant mineral in the Zomba soils, appears to be derived entirely from the breakdown of the alkali feldspars, orthoclase and sodic plagioclase. A close parallel apparently exists between the type of weathering at Zomba and at Mlanje, where, on the Lichenya plateau, the hornblende–syenite is overlain by a quartzose bauxitic capping (Dixey, *Miner. Mag.* 1925, **33**, 201–5), and the other occurrences of the " high-altitude soils " are probably of a comparable strongly weathered nature. At Zomba these soils in general range from red to yellow latosols and are well drained, but locally in depressions seepage water has led to the development of humic gley soils, which occasionally closely resemble peaty podzolic soils in character. It is intended to extend the work in the area to compare the well-drained latosols with their poorly drained associates. (Stephen.)

Micropedology

The construction by G. C. Dibley of a machine that cuts slices of rock and suitable impregnated soil specimens to approximately 1 mm. thick has greatly decreased the time taken to prepare thin sections. Sections from peds of some surface soils from experimental

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plots at Rothamsted and Woburn, both in the undisturbed state and after comminution and deep freezing, were prepared and examined in connection with work being done in the Chemistry Department on pore-space, size and distribution.

Thin sections made from some Russian podzolic soil profiles showed that sandy podzolic soils had a micromorphology similar to that of the iron or iron–humus podzol as defined by Kubiëna, whereas the podzolic soils on heavier textured materials were related to sols lessivés. (Stephen, Osmond and Bullock.)

Mineralogy

Heavy mineral analyses

The " heavy residues " from some soils and sedimentary deposits were studied in connection with field problems encountered by members of the Soil Survey staff. The materials examined include shallow, brown, flinty, calcareous soils of silty clay or silty clay-loam texture on chalk in Hampshire and Yorkshire. The suite of minerals in these soils bears a general resemblance to the assemblages found to be characteristic of loesslike deposits in southern England. Reading Beds and Lower Greensand deposits in Hertfordshire and Essex were also studied to determine their possible contribution to the glacial gravels of the area.

The composition of the very fine sands of a profile from Broadbalk Wilderness Meadow (Soil Survey No. Ht. 38) was studied in detail. The soil has been classed as a Winchester (shallow Batcombe) silt loam. Previous studies of Batcombe and Winchester profiles from the Chilterns showed that the parent material is non-uniform with less-weathered material, presumably of loessial origin, in the surface horizons (Loveday, 1958, Ph.D. thesis, Lond. Univ.; Avery *et al.*, *J. Soil Sci.* 1959, **10**, 177–95). Similarly, in the Broadbalk soil the presence of more than one type of parent material is suggested by the mineralogical data—feldspar being more prominent in the solum above 16 inches than in the basal layer (Table 1). This is shown in both size-fractions examined, but is more pronounced in the 0·08–0·05-mm. grade. Whether the added material is of loessial character cannot be determined, of course, from mineralogical evidence alone, but would require detailed particle-size distribution studies. One point of interest, however, is that heavy residues rarely contain garnet, a mineral previously found to be characteristic of the silty surface horizons of Batcombe and Winchester profiles in other parts of the Chilterns.

The presence of appreciable amounts of andalusite throughout the Broadbalk profile is noteworthy. Previous studies of subsoil horizons of Batcombe and Winchester profiles show their heavy mineral suites to be closely correlated with those of Reading Beds—zircon, tourmaline, rutile, staurolite and kyanite constituting the bulk of the separates (Table 1, A and B). In materials examined by Wooldridge and Ewing andalusite never exceeded 0·5% in Reading Beds, but was characteristic of Pliocene deposits (now considered as early Pleistocene), accompanied by monazite and green spinel (Table 1, C). Monazite occurs in small amounts throughout profile Ht. 38, but green spinel has not been observed. Nevertheless, the

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large differences in amount of andalusite compared with other Batcombe and Winchester profiles merit consideration of a possible Pleistocene origin for much of the material constituting the profile. It is of considerable interest in this connection that ferruginous sandstone of Red Crag age was described by Dines and Chatwin (*Summ. Progr. geol. Surv. Lond.* 1929, pt. III, 1–7) among material

TABLE 1

Mineral Distribution

	Profile Ht. 38						
	1–5 in.	6–10 in.	12–16 in.	30 in.+	A	B	C
Feldspar in light separates, %							
0·1–0·08 mm. ...	2	3	1½	½–1			
0·08–0·05 mm. ...	10	8	10	3			
Heavy minerals (0·1–0·08 mm.), %							
Zircon	36	37	22	20	51½	36½	53
Tourmaline ...	26	32	32	41	22½	38	12½
Rutile	14	13	14	9	9	5½	10½
Garnet	—	—	1	—	—	—	—
Staurolite ...	10	9	8	11	8	15½	8
Kyanite	5	3	7	7	3	4½	9
Andalusite ...	6	4	9	9	—	—	7

Note: Only the most commonly occurring heavy minerals are listed. A, average of numerous samples, Reading Beds, Lane End; B, average of samples of Reading Beds from the main outcrop at Batchworth Heath, Sandy Lodge and Watford Heath; C, average of high-level Pliocene deposits, Little Heath and Lane End. (Wooldridge and Ewing, *Quart. J. geol. Soc. Lond.* 1935, **91**, 293–317.)

from a trench running from north-east to south-west across West Barnfield, and fragments of the sandstone were also found on Sawyers and along the western boundary of Long Hoos. (Stephen.)

Rectorite and allevardite

Three samples of allevardite, from Allevard, France, from Baluchistan and from Dagestan, Caucasus, the last kindly given to us by Dr. Kotelnikov, Institute of Geology and Exploitation of Caustobiolites, U.S.S.R., were compared with a sample of rectorite from Arkansas (U.S.N.M. 80607). Extensive X-ray-diffraction studies show that all give very similar patterns under a variety of conditions and treatments. The morphology shown by electron microscopy and chemical composition are also similar. This work suggests that the names rectorite and allevardite are synonymous, rectorite having priority.

Ivkin, Kitaigorodsky, Kotelnikov, and Korolev (*Mem. All-Union Miner. Soc.* 1959, **88**, 554–563) in their description of the Dagestan material index 00*l* reflections on the basis of a superlattice of period 4 × 25 Å. for the air dry material. Drs. Korolev and Kotelnikov informed us that they found a basal reflection of 50 Å. spacing from both Dagestan and Baluchistan allevardites and also sent their patterns, showing this reflection, which had been taken with filtered radiation. We had not observed this reflection with our cameras.

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Examination of the allevardites and rectorite with crystal-reflected radiation, with an experimental arrangement capable of recording spacings up to 80 Å., also failed to show any trace of this reflection, which must therefore be attributed to "white" radiation. The other superlattice reflections which they observe can probably be attributed to:

(i) The simultaneous presence of more than one hydrate leading to more than one set of 00*l* reflections.

(ii) Impurities. For example, Baluchistan allevardite often contains small quantities of mica with a 10 Å. basal spacing, and a chlorite impurity with a 14 Å. basal spacing is unevenly distributed in our sample of Dagestan allevardite. (Brown and Weir.)

Clay mineralogy

The following samples were analysed for clay minerals. For the Soil Survey of England and Wales 128 samples, for the Colonial Office 36 samples from Borneo and 107 specimens of soil clays, minerals and other materials from Britain and overseas. Of the 271 samples, 247 were analysed for clay minerals.

Red and brown soils from Borneo show marked differences in their clay mineral content, which are to some extent linked with the parent materials. Thus, soils on sandstone and shales show dominant mica in the clay, whereas one soil on basalt showed dominant kaolin, another on basalt colluvium showed dominant vermiculite. The alluvial and coastal soils from Malaya are variable in their clay minerals: a very acid coastal plain soil from Kedah contained mainly montmorillonite; an alluvial soil from Selangor was mainly kaolin, as was another from North Kelantan. The alluvial soils from Borneo all had a high clay mica content.

Work on the Old Red Sandstone sediments from the West Midlands was delayed by other work, and has not proceeded as quickly as we would have liked, but forty-seven samples from our collection were examined. (Du Feu and Brown.)

Physical Chemistry of Soil Minerals

Optical properties of clays

The work described in last year's Report was continued, and the validity of the current method of determining the optical constants of clay aggregates was examined. This method consists of immersing aggregates in non-penetrating mixtures of liquids of differing refractive indices and determining the point of minimum relief. The assumption that the solid index equals the liquid index at minimum relief is valid only when there is no form factor. Usually the indices determined are not the true ones, and their difference, that is the birefringence, bears little relation to the correct value. The possibility of using penetrating liquids, and compensating for any form factor, is being studied.

The relation was established between the difference in birefringence when a dry montmorillonite aggregate is complexed and the polarisabilities of the intercalated molecules. More detailed

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study showed small differences that must be due to changes in the molecular polarisabilities on sorption. (Greene-Kelly.)

Surface studies

The specific surfaces of aggregates formed from mixtures of suspensions of clay minerals were measured by nitrogen adsorption, and the results have shed light on the structure of Na-montmorillonite aggregates. It was earlier suggested that these aggregates are composed of a random collection of oriented silicate layers with little or no formation of stable sub-units (e.g., crystals). The conclusion from our experiments is that there are sub-units present.

The calorimetry of clay–water systems, from room down to low temperatures, began, and the freezing and the heat capacity of the sorbed water films will be studied as a function of exchange cation. (Greene-Kelly.)

Hydrothermal synthesis of clay minerals

The main work this year was an examination of the rate of formation of kaolinite from a co-precipitated silica gel. 0·5-g. samples were heated with 1 ml. of water in a gold capsule in a small autoclave sealed with a copper disk. The products were shown by electron microscopy to consist of aggregates of about the same size as the particles of gel used (which had been ground to pass a 300-mesh sieve) and had crystalline laths growing out in all directions. This morphology allowed X-ray-diffraction measurements of the quantity of kaolinite present to be made more accurately than for kaolins containing separate platelets, with which there is always strong preferred orientation in the surface layers of the sample exposed to the X-ray beam. The amount of kaolinite measured in this way was closely correlated with that found by thermogravimetry.

The reaction roughly followed a first-order law, and after a week at 300° was, as far as could be measured, complete. The time taken for half the material to be converted was about 8 hours at 300°, about 1½ days at 260° and about 11 days at 220°. At 180°, conversion of part of the material to kaolinite had just detectably begun after 7 days.

It is hoped that experiments at lower temperatures for longer times will enable the rate of reaction likely at the temperatures found at the earth's surface to be estimated, and that this estimate will not be invalidated by an unknown change in the nature of the reaction occurring below the lowest temperature at which measurements are made. An invalid result would almost certainly be obtained if the extrapolation was made from the present results, as they show some change in the degree of order in the kaolinite crystals formed as the temperature changes from 300° to 220°. (Rayner and Greene-Kelly.)

Spectrochemistry

Further work was done in connection with the danger of poisoning plants by heavy metals contained in sewage sludge contaminated by industrial waste.

The previous work, mainly on sugar beet, drew attention to the

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possibility of similar trouble occurring in the Market-garden Experiment at Woburn, in which sewage sludge was used. Extracts from the sludge and from the soils in the plots to which it had been applied indicated an appreciable contamination of the soil by zinc, copper, nickel, chromium and lead. Successive crops of leeks and globe beet grown on these plots were also analysed for these elements. The leeks from the sludge-treated plots contained significantly more zinc, nickel and copper than those on the untreated plots, and the globe beet contained more zinc and nickel.

Sitka spruce seedlings suspected by the Forestry Commission to be stunted and discoloured because of the heavy metals were analysed, but the suspicion was not confirmed. Many other spectrographic examinations were made, both for workers at Rothamsted and elsewhere, including trace-element surveys of soils from North Borneo and St. Helena for the Colonial Office. Consultative work of this kind occupied most of one worker's time throughout the year.

Work on the general levels of trace elements in the soils of southern England include attempts to identify constituents of the soils with which the various elements are associated.

The brown and grey forms of London Clay were compared to ascertain why the grey clay weathers brown at and near the surface more than do some other sedimentary deposits. Specimens traversing the brown to grey transition in a quarry near Workingham were examined. The most notable differences lay in their contents of FeS_2 and $CaSO_4$ (0·03–0·1% of both in the brown compared with 0·5–0·7% FeS_2 and 0·3% $CaSO_4$ in the grey). The grey also contained more $CaCO_3$ and organic carbon, but the difference was not as great. These London Clays differ strikingly from the Lower Lias shales in their contents of $CaCO_3$, organic C and FeS_2. Whereas average values for these in the grey London Clay were 3, 0·4 and 0·6% respectively, corresponding values for a typical Lower Lias shale were 30, 8 and 6%. These figures, indicating a much more reduced environment in the Lias, seem to offer an adequate explanation for the greater ease of oxidation of the London Clay. Added to this is the fact that at the site where these specimens were taken the material is much sandier (about 50% $>$ 20 μ) than the Lias, making it relatively porous and thus weatherable to a greater depth. Further evidence that leaching readily occurs is provided by the lower concentrations of $CaSO_4$ oxidisable FeS_2 and organic matter in the brown than in the grey clay. (Le Riche and Burnett.)

Equipment for the direct-reading spectrographic-determination of magnesium was made and is now under test. (Weir.)

Soil Chemistry

Effect of soil waterlogging

Molybdenum co-precipitated with ferric oxide is mobilised by the action of anaerobically decomposing plant material, but the ferrous iron formed causes the pH of the mixture to rise, so solution of Mo could result simply from greater solubility of molybdate at alkaline reactions. However, adding plant material to a soil before incubation increases the amount of Mo extracted by either water or neutral or acid ammonium acetate, although the pH of the

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reaction mixture is consistently lower in the presence of added plant matter. In a typical example, the water-soluble Mo in a soil was increased approximately eight times by incubation with dried grass, although the pH of the reaction mixture remained almost constant at 5·3, so the mobilisation of Mo in poorly drained soils is clearly not merely a pH effect.

Mo dissolved from ferric oxide co-precipitates by fermenting plant material is readily co-precipitated with ferric oxide when the fermentation solution is exposed to the atmosphere; this suggests that the Mo persists in its original anionic form throughout the fermentation. This also appears to be true for vanadium. The order of ease of co-precipitation of minor elements with ferric oxide obtained was Mo, V > Sn, Pb > Zn > Cu > Co, Ni, Mn, which agrees with the evidence provided by analyses of ironstone and lateritic concretionary materials.

It was reported previously that Cu is irreversibly sorbed by the fibrous constituents of undecomposed plant material. Ni, Pb and Zn behave similarly, and Co and Mn are fixed to a much smaller extent. This fixation suggests a parallel with the low availability of Cu in many organic soils, which causes "reclamation sickness" on fenlands. An attempt was made to see how far the fixation by peat results from "humification", and how far it is a persistent property of the original plant material. Weight for weight of oven-dry ash-free material, phragmites peat fixes much more Cu or Ni than fresh phragmites fibre, and the fixing capacity of peat is considerably reduced after removing humified material by a mild reagent such as neutral ammonium oxalate. Removal of pectins decreases the fixing capacity of the fresh fibre, so it is apparent that, although one potential fixing agent, i.e., pectin, is destroyed during peat formation, humification involves the formation of compounds that can also fix relatively large amounts of Cu, etc. Removal of benzene-soluble material or protein from both peat and phragmites fibre increases the fixing capacity of the residue, so that these experiments give no indication of the extent to which these constituents contribute to the fixing properties of the original materials. The increased fixing capacity of the benzene-extracted material is probably largely a result of the less hydrophobic nature of the product, but it seems unlikely that proteins would not contribute to the fixation of Cu for example; removing protein thus appears to expose more reactive sites on the lignin-cellulose residues. (Bloomfield, Ng Siew Kee, Greet and Pruden.)

A method for determining total sulphur in soils is required in connection with a projected study of the reduction of sulphate in waterlogged soils. A procedure involving igniting the soil in a quartz tube in the presence of V_2O_5 was developed, and shows promise of providing a rapid and accurate method for determining total sulphur. The sulphur is evolved as SO_3, which is collected in dilute hydrogen peroxide; the resulting sulphuric acid can then be determined titrimetrically. (Bloomfield.)

An experimental approach, used to find out how calcium carbonate is removed, moved or accumulated as a calcareous horizon in soil profiles, showed that $CaCO_3$ can be leached quite readily out of columns of siliceous sand that are percolated with CO_2–water.

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When the partial pressure of CO_2 in the water is reduced to a level at equilibrium with laboratory air, a small amount of calcium carbonate is removed initially, but the bulk is unaffected. Carbonate was always removed from the top rather than from the layer as a whole. When tap water, containing about 0·4 g./litre of dissolved solids, is percolated through the columns there is partial removal of solids as the water passes through a calcium carbonate layer. (Wells.)