LOSE LÖSS-BRIEFE

LOESS LETTER 32

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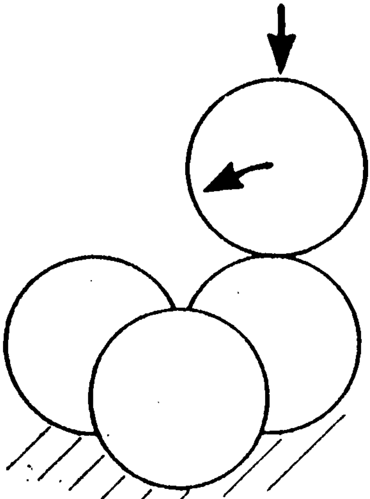

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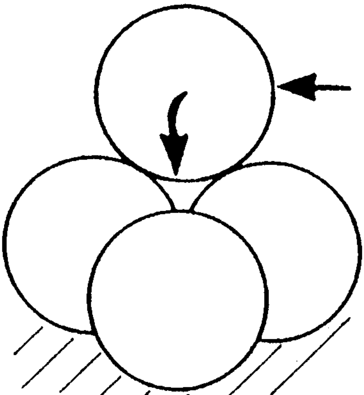

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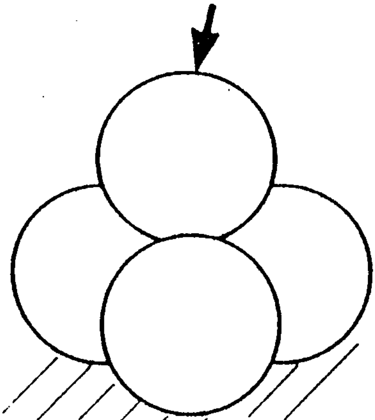

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LOESS LETTER 32: OCTOBER 1994

L32 is a special issue devoted to a single topic -Soil Structure and Particle rchitecture in Loess (and in other soils and sediments). It follows thematically om LL31 which was published to coincide with the NATO Collapsing Soils orkshop at Loughborough University in April 1994. It became apparent during iscussions at the NATO Workshop that a whole range of investigators is interested 'soil structure' and it was decided that it might be worthwhile to form a discussion roup to consider various aspects of particle arrangement in soils and sediments nvolving engineers and geomorphologists as well as soil scientists).

o offer a few contemporary views LL32 contains three extracts from papers and ports which touch on the soil structure theme; these are a paper in Soils and illage Research by Prof. Dr. Rainer Horn and colleagues from the Institute of Plant lutrition and Soil Science at Christian-Albrechts University in Kiel, Germany; a aper by Drs. G.J. Churchman and R.C. Foster of CSIRO Soils Division at Glen smond in South Australia which was presented at the ISSS Conference in Acapulco July 1994; and a report by Dr. L.P. Wilding, President of the Soil Science Society of merica from the February 1994 issue of Geotimes. It is noteworthy that hurchman and Foster, and Wilding, use the terms 'architectural arrangement' and n-situ architecture of a soil' when discussing particle arrangements and structures: is is what we want to discuss, the statement by Wilding (LL emphasis added) is xactly what the proposed new group will consider.

is proposed that the INQUA Loess Commission might initiate the formation of is project. The Commission organisation within INQUA is probably going to be vised at the Berlin 1995 meeting, with some emphasis being given to the rmation of inter-disciplinary projects. A 'soil structure' group might well fit omfortably into the new INQUA.

he LL32 message is that soil scientists, ground engineers, geomorphologists, eologists and Quaternary investigators are invited to join a working group to iscuss and investigate 'the in-situ architecture of a soil'. We start with loess, ecause that is the business of the Loess Commission, but also because it might be onsidered, in structural terms, to be a fairly simple soil or sediment.

Our starting position is essentially geographical and geotechnical. Contact, in the first instance:

Ian Smalley, Centre for Loess Research and Documentation
Geography Department, Leicester University, Leicester LE1 7RH, UK
Fax: 0533 523854.

Ian Jefferson, Civil and Building Engineering Department
Loughborough University of Technology, Loughborough, Leics. LE11 3TU, UK. Fax: 0509 610231. E-Mail: i.jefferson@LUT.ac.UK.

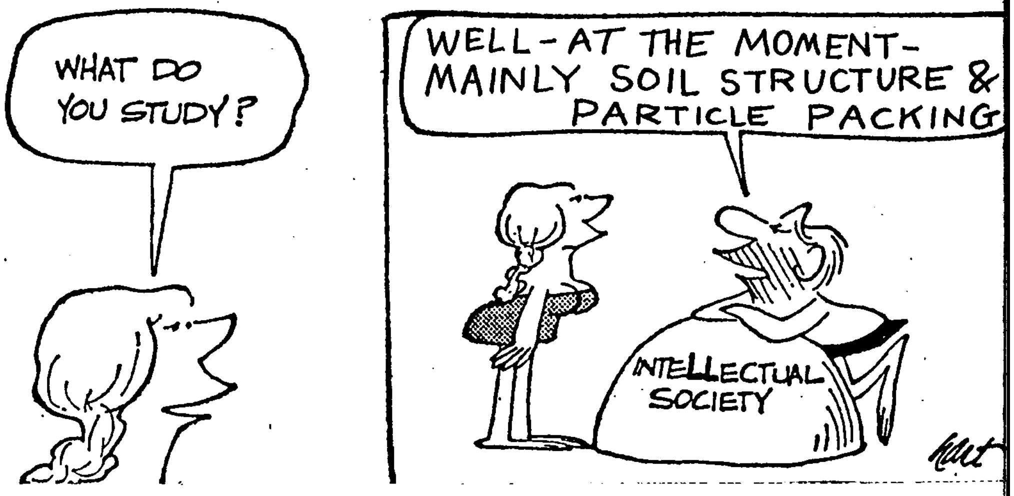
We have published two initial reviews, for discussion and to launch the group literature: see

Rogers, C.D.F., Dijkstra, T.A. and Smalley, I.J. (1994) Particle packing from an Earth-science viewpoint. Earth Science Reviews 36, 59-82.

- (1994) Hydroconsolidation and subsidence of loess: studies from China, Russia, North America and Europe. Eng.Geol. 37, 83-113.

These give some idea of the Leicester/Loughborough viewpoint and indicate some current concerns.
Contact is being made with members of various international associations i.e. International Association of Geomorphologists IAG, International Association of Engineering Geology IAEG, International Society of Soil Science ISSS, International Union of Geological Sciences IUGS, International Society of Soil Mechanics and Foundation Engineering ISSMFE, and International Union for Quaternary Research INQUA. All members/interested parties are warmly invited to contribute and participate. First actual face-to-face discussions will probably be held at the main INQUA meeting in Berlin August 1995, most likely at the Loess Commission meetings.

Loess Letter LL is the newsletter of the INQUA Loess Commission. It is published twice a year, in April and October. For more details contact Ian Smalley at Leicester. The cover picture for LL32 comes from 'Particle Packing Characteristics' by R.M. German, Metal Powder Industries Federation, Princeton, New Jersey 1989 (see p.54).



The Role Of Clay Minerals In The Maintenance Of Soil Structure

J. **Churchman*** and **R.C. Foster** *CSIRO Division of Soils and Australian operative Research Centre for Soil and Land Management, Private Bag No. 2, n Osmond, South Australia 5064, Australia.*

tract. Scanning electron microscopy carried out using an environmental cell showed that, in a ic Rhodoxeralf in South Australia which has never been cultivated, sand-size quartz particles largely covered by clay-size particles that are closely attached to the quartz. Samples from by cultivated plots in the same soil type had many uncoated quartz particles. Transmission tron microscopy of ultrathin sections revealed complex multilaminate microaggregates of silt . The cores of these microaggregates are variously composed of quartz, plant cell remains, acellular polysaccharides and microbial colonies. In the virgin soil, clay minerals largely occur omains or tactoids within microaggregates while, in cultivated soil, much dispersed clay also rs in micropores between microaggregates. Particle size distributions following treatments either hydrogen peroxide or sodium citrate/bicarbonate/dithionite indicate that clay in the in soil is more strongly bound by Fe and Al compounds than by organic matter. However, pounds of Fe and Al are no more effective than organic matter for binding clay in the vated soil.

stability of associations of <2μm particles against shaking generally increased with increases e specific surface areas of soils as measured by nitrogen sorption. Some acidic kaolinitic soils ulated on shaking. Many Australian illitic and smectitic soils flocculated on shaking.

mectitic soils showed spontaneous dispersion and sometimes also macroscopic swelling upon sis against water. Na-illitic soils showed spontaneous dispersion but not macroscopic ling in water. Na-kaolinitic soils with a range of specific surface areas and associated minerals ved no dispersion or swelling in water. Charge and particle size appear to govern the effect of otic forces on soils.

oduction. Soil structure encompasses both the "architectural arrangement" of primary cles in a soil (1), and also the arrangement of its voids or pores (2). Good soil structure nces plant growth. It provides fine pores for the storage of water, coarser pores for the mission of air, water and nutrients to roots as well as for the drainage of excess water, and even coarser pores to enable the establishment and extension of roots. These different pores ld be stable towards disturbance by most climatic, animal and agricultural management ences. A good soil structure should also provide easy workability as well as resistance to the ve forces of wind and water.

very occurrence of stable pores, as well as the distribution of their sizes and shapes is itself a equence of the aggregation of the primary soil particles. Aggregates in soils comprise ciations of particles which are stronger than loose stacks of sand grains but weaker than nted soil features like iron concretions and nodules.

minerals have: 1. high surface areas, 2. electrical charges, 3. the ability to disperse and me flocculated and to swell and shrink, and 4. a variety of particle shapes. Because of their surface areas, which derive from their small sizes, and also their charged nature, they form g associations with other soil particles which are small and/or charged. These include oxides, oxides and oxyhydroxides of Fe and Al, which also have high surface areas. These "metal s" are (variably) charged (3,4,5). Clay minerals also associate with organic matter. At the pH's of most soils organic matter typically has a negative charge which is comparable to, greater than, that of the most highly-charged clay minerals ie. smectites and vermiculites (6).

According to early mechanisms for the stabilisation of aggregates, either clays provide continuous network that enmeshes and binds other soil particles together, or soil particles are h together by irreversibly dehydrated silicates, oxides and hydroxides of iron and aluminium, humic-sesquioxide complexes (7). It has also been suggested (8) that clays and organic matter linked together to form the basic unit of soil aggregates, with successively larger entities bearin fractal type of relationship to this basic unit. Tisdall and Oades (9) proposed a hierarchical mo in which a stable soil structure is based on strong mutual associations between the finest inorga ie. clay particles. These associations are bound into successively larger entities by a variety aggregating agents of largely organic origin. According to Tisdall and Oades (9) water-sta macroaggregates (>*c.* 200μm), but not microaggregates (<*c.* 200μm) are affected by agricultu practices. Others eg. (10), however, have found that agricultural practices can affect distribution of water-stable microaggregates in soils.

Electron microscopy enables the direct observation of the structure of soils at the finest scale. has indicated that mechanisms for the stabilisation of associations of soils can vary with soil ty (11). These variations probably relate to differences in clay mineralogy.

In order to clarify the role of clay minerals in the stabilisation of the structure of soils, we studi associations formed by clays in an agriculturally important type of soil and the effects of farmi practices upon these associations. We also carried out some experiments on the stability associations of clays in soils relative to common disruptive forces. In particular, we tested a rec suggestion (12) that the resistance of soils to mechanical disruption may be closely related their specific surface areas (hereafter "surface areas"). We also investigated factors influencing t effect of osmotic forces on soils. Osmotic forces affect sodic soils, which are widespread Australia (13) This paper reports the results of the electron microscopic and laborato investigations.

Materials and Methods. *Form of occurrence of clay minerals in an agricultural soil.* C samples were taken of a Calcic Rhodoxeralf from the sites of tillage and crop rotation trials bei conducted by the South Australian Research and Development Institute at Halbury, *c.*90km N. Adelaide, South Australia. Core samples of a Calcic Rhodoxeralf were also taken from the site a former school, 700m from the trial sites that has never been cultivated. Soils were sampled the trial sites on each of duplicate pairs of plots. One set was under conventional cultivation an rotation of legumes (alternately peas and beans) with wheat. The other set was under zero tilla management and a rotation of pasture and wheat. The trials had been conducted for 18 years a followed approximately 100 years of farming.. Soils in each of the 5 sites were sampled at dept of 0-10, 10-20, 20-50mm. These duplex soils were also sampled at successive intervals of up 50mm until the clay-rich B horizon was reached. The pH (in water) of the virgin soil was 7 between 0 and 200mm depths while that of the cultivated soil at 0-100mm depth was 7. Combined analyses by X-ray diffraction (XRD) and X-ray fluorescence (XRF), including analys for cation exchange capacity (CEC) from the exchange of Ba^{2+}, showed the clay fraction of t soil in the uncultivated and also the various cultivated sites was dominated by a mine comprising illite and smectite layers in random interstratification. Kaolinite was also present minor proportions (< 20%) and quartz in trace amounts (< 5%).

Interstratifications of smectite with either illite or kaolinite, generally designated as "random interstratified minerals", or RIM, are common in Australian soils (14). They can have high CEC and can also confer to soils many of the physical properties of smectites eg strong shrink-sw characteristics.

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Soil & Tillage Research

Soil physical properties related to soil structure

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(Accepted 30 December 1993)

bstract

The aim of this paper is to clarify the effect of soil aggregation on soil physical and ıemical properties of structured soils both on a bulk soil scale, for single aggregates, as ell as for homogenized material. Aggregate formation and aggregate strength depend on velling and shrinkage processes and on biological activity and kinds of organic exudates ; well as on the intensity, number and time of swelling and drying events. Such aggregates 'e, most of all, more dense than the aggregated bulk soil. The intra-aggregate pore distri-ıtion consists not only of finer pores but these are also more tortuous. Thus, water fluxes aggregated soils are mostly multidimensional and the corresponding water fluxes in the tra-aggregate pore system are much smaller. Furthermore, ion transport by mass flow as ell as by diffusion are delayed, whereby the length of the flow path in such tortuous finer ›res further retards chemical exchange processes. The chemical composition of the per-ılating soil solution differs even more from that of the corresponding homogenized ma-rial the stronger and denser the aggregates are.

The rearrangement of particles by aggregate formation also induces an increased appar-ıt thermal diffusivity as compared with the homogenized material. The aggregate for-ation also affects the aeration and the gaseous composition of the intra-aggregate pore ace. Depending on the kind and intensity of aggregation, the intra-aggregate pores can completely anoxic, while the inter-aggregate pores are already completely aerated. The gher the amount of dissolved organic carbon in the percolating soil solution, the more onounced is the difference between the gaseous composition in the inter- and in the tra-aggregate pore system.

From the mechanical point of view, the strength of single aggregates, determined as the gle of internal friction and cohesion, depends on the number of contact points or the rces, which can be transmitted at each single contact point. The more structured soils ɜ, the higher the proportion of the effective stress on total stress is, but even in single gregates positive pore water pressure values can be revealed. Dynamic forces e.g. due to ıeeling and/or slip processes can affect the pore system as well as the composition of the il by: (1) a rearrangement of single aggregates in the existing inter-aggregate pore system resulting in an increased bulk density and a less aerated and less rootable soil volume, (2 a complete homogenization, i.e. aggregate deterioration due to shearing. Thus, the smalle texture dependent soil strength coincides with a more intensive soil compaction due t loading. (3) Aggregate deterioration due to shearing results in a complete homogeniz tion, if excess soil water is available owing to kneading as soon as the octahedral shea stresses and the mean normal stresses exceed the stress state defined by the Mohr–Coulom failure line. Consequently, normal shrinkage processes start again.

Thus, the rearrangement of particles and the formation of well defined single aggregate even at the same bulk density of the bulk soil both affect, to a great extent, various ecological parameters. Environmental aspects can also be correlated, or at least explained wit the processes in soils, as a major compartment of terrestrial ecosystems, if the physical an chemical properties of the structure elements and their composition in the bulk soil ar understood.

Keywords: Aggregate formation; Soil structure; Hydraulic process; Chemical property; Soil aeratio Mechanical effect

1. Introduction

As long as 100 years ago, Wollny (1898) described the positive effect of soi structure on root growth, water availability, gas transport in soils as well as th positive effects of soil structure on soil strength. He mentioned that the mechanisms involved in the interaction between soil structure and plant growth an yield need to be investigated. Since then, the positive effects of a favourable soi structure and negative effects of e.g. soil compaction on crop growth and/or yiel have been repeatedly described (e.g. Blank, 1932–1939; Dexter, 1988; Håkansson et al., 1988; Kay, 1990). Although it was often speculated why crops respon favourably to good soil structure, reasonable experiments to convince both farmers and scientists are up to now rather rare, even if not only texture dependen parameters and bulk density data but mainly structure dependent data were included. Emmerson et al. (1978) pointed out interactions between soil structure water status of structured soils, as well as soil aeration and root growth expresse as rootability and/or compressibility of arable land. How far soil structure ma affect root growth as well as ion transport e.g. intro- and extro-directed iron an manganese movement as a function of pore systems, water saturation and redo reactions, can also be derived from data published by Blume (1968). Thus, Dexter (1988) defined soil structure as "the spatial heterogeneity of the differen components or properties of soil" at various scales. Bouma (1990) amongst others has repeatedly pointed out that not only the determination of the amount an diameter of pores but also the function and the distribution of solid phase an pores as well as their connection define the ecologically important soil properties This is especially true with respect to the accessibility of the particle surfaces t water, ions and gases.

Thus in the following, the present state of knowledge on aggregate and structure processes and properties is summarized as far as the literature available allow and fitted in the broader picture of ISTRO's interests. However, those papers which only deal with bulk density dependent changes in physical and chemical

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Soil Science

The thin skin at the earth's surface known as soil is the primary reason life is possible on this planet — this is the life-sustaining pedosphere zone. This biologically active, porous, and structured medium is an effective integrator and dissipater of mass flux and energy; a sustainer of biomass productivity; the foundation upon which structures are built; the fabric to which organisms are anchored; the repository of solid and liquid wastes; and the living filter for bioremediation of waste products and water supplies. Soil is the long-term "capital" on which a nation builds and grows. It is the basic component of ecosystems and ecosystem management.

Soil science focuses primarily on near-surface processes that govern the quality and distribution of land resources relative to evolution, geochemical environment, and organismal habitat. Soil science had its parentage in geology, chemistry, and biology, but for the last 100 years, it has evolved as an independent body of knowledge with strong underpinnings to agriculture. Because of the unparalleled success that applied soil science has enjoyed in helping to bring ample food, fiber, feed, and fuel to the world, the development of basic soil science has come primarily as a byproduct of research in agriculture, engineering, and environmental management. There is growing evidence that the complexity of these problem areas requires a much broader approach to the science of soil than can be stimulated by applied research alone. Soil science must take its place alongside basic research efforts in the biosciences, geosciences, and atmospheric sciences to provide the reservoir of fundamental understanding needed to develop lasting solutions to the challenges of balanced use and stewardship of Earth.

Recent acceptance of the International Soil Science Society into the International Council of Scientific Unions is an opportunity for soil science to take its place at the table with other pure sciences. Likewise, recent plans for affiliation of the Soil Science Society of America with the American Geological Institute affirms that soil science is a true geoscience with boundaries well beyond the limits of agronomy and agriculture.

Opportunities for soil scientists to continue probing research frontiers in subjects of national and international importance are unlimited. Such strategic, mission-oriented research should be conducted in close collaboration with other geoscientists. The design and execution of research should reflect cross-disciplinary geoscience expertise with a soil science presence. Examples of such priority research endeavors include:

- environmental protection and enhancement of air, water, and soil resources;
- use and preservation of wetlands;
- waste product management;
- food sufficiency and safety;
- global climatic change;
- reclamation and rejuvenation of degraded lands; and
- public literacy in the earth sciences (K-12 educational agenda).

What is commonly missing in past research is a knowledge of fundamental processes. This information is necessary to model pedogenic functions and to extrapolate knowledge beyond a given site or experimental unit. Uncertainties in models become particularly acute when projecting research information from microlevels to macrolevels of resolution, from submicroscopic to global-scale systems. Another factor is how the in-situ architecture of a soil, especially at the microscale, governs physical, chemical, and biological behavior, such as water flow, movement of chemicals, activity of microorganisms, and root growth.

The visions and directions of soil science are changing. The profession, soil scientists, and the public support changing paradigms and mandate closer linkages with geoscientists.

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