N89-18356

SOIL MICROSTRUCTURE AND ELECTRON MICROSCOPY

P.Smart and J.R.Fryer
Depts. of Civil Eng. & Chemistry (resp.),
University of Glasgow, Glasgow G12 8QQ, Scotland.

As part of the process of comparing Martian soils with terrestial soils, high resolution electron microscopy and associated techniques should be used to examine the finer soil particles, and various techniques of electron and optical microscopy should be used to examine the undisturbed structure of Martian soils.

Speculation regarding the optical microstructure of the fine– grained portions of Martian soils ranges ranges from: (a) erde– structure, i.e. very small sub– spherical grains with both inter– and intra– crumb voids (residual from a previous climate); (b) salt– dominated (as in terrestial evaporite sediments); (c) freze– thaw– dominated; to (d) remoulded (by meteorites). Sections 30 μm ground from undisturbed blocks of impregnated material would help to differentiate between these hypotheses, reveal signs of illuviation or other unsuspected proceses, permit conventional optical mineralogy on the larger grains, and provide comparisons with terrestial soils. Little mechanical disturbance could be tolerated, and terrestial trials of the sampling gear would be needed. Temperature, pressure, and radiation would be less important. Use of a hard resin for impregnation (rather than Carbowax) would yield sections which could be passed from laboratory to laboratory and retained in museum conditions for a reasonably long life. Two sizes of sections are preferred: on slides 26 mm x 45 mm for universal stages; and samples say 25 mm x 50 mm upwards for an overview.

Supplementary observations using stereo– microscopy (and perhaps multi– spectral scanning optical microscopy) should be made on air– dry material. Mechanical disturbance is slightly less important and high temperature more important than for thin– sections. A microscope could be sent to Mars; but this non– destructive technique should be used to monitor other techniques on Earth.

A full series of micro– spectro– photometric analyses from ultra– violet to infra– red would support remote sensing. Disturbed material seems permissable; but the effects of heating and de– and re– hydration would be important.

Observation and classification of fracture surfaces of dry samples in scanning (reflection) electron microscopes is a well developed technique, which informs about both genesis and properties (6,7). Sampling requirements are somewhat similar to stereo– microscopy.

To examine the structure of fine– grained portions of the soil, transmission electron microscopy may be required. In the past, ultra– thin sections have been cut in an ultra– microtome from impregnated material; but ion beam thinning often gives better results (7). Ultra– microtomy can use samples as small as 1 mm cube; but larger samples are preferable, and it may be necessary to discard 1 or 2 mm on all sides of the final block to avoid the disturbance caused by cuting this block. Ion beam thinning often starts from discs 3 mm dia overcored from thin sections 30 μm thick and yields one ultra– thin sectrion per disc. Sampling requirements are somewhat similar to thin– sectioning.

SOIL MICROSTRUCTURE AND ELECTRON MICROSCOPY

P.Smart and J.R.Fryer

A striking feature of many Martian soils is their red colour. Although the present-day Martian climate appears to be cold, this colour is reminiscent of terrestial tropical red clays. Their chemical contents are broadly similar (2); and their optical reflectance spectra are similar to those of amorphous Hawaiian soils (e.g. 4). It is important to examine the iron oxides and hydroxides (and clay particles) in Martian soils directly to study their nature (morphology, crystal structure, cation exchange properties), their modes of formation (mechanisms of crystal growth and of aggregation), and their interactions with each other and with the clay minerals with which they are associated. Iron (hydr)oxides 5 nm dia have been found in terrestial soils (5) and require specialised techniques of high resolution electron microscopy and electron diffraction (1,3). To examine the (hydr)oxides themselves, disturbed samples are adequate; but the temperature and humidity requirements may be severe.

Assuming the pores of the soil in situ to be almost full of almost completely frozen water, the simplest procedure would be to lower the temperature to freeze the rest of the water, and to do as much observation as possible at this low temperature. Use of a high temperature to sterilise the soil might change some of the iron (hydr)oxides and clay minerals, also it might be necessary to use freeze-drying to remove the water first. Alternatively, it might be possible to develop a method of super-critical drying which both removed the ice and water and sterilised the remaining material. Sterilisation by fixing with chemicals such as osmium tetroxide or glutaraldehyde should also be considered (7).

(1) Baird, T., Fryer, J.R., & Galbraith, S.T. 1978. 9 Int. Cong. E.M., Toronto. 1, 264-5.

(2) Clark, B.C., & 5 others. 1979. J. Geophysical Res. 87B, 10059-67.

(3) Fryer, J.R. 1979. Chemical applications of transmission electron microscopy. Academic Press, London.

(4) Singer, R.B. 1982. J. Geophysical Res. 87B, 10159-68.

(5) Smart, P. 1973. Q. J. Eng. Geol. 6, 129-40.

(6) Smart, P., & Tovey, N.K. 1981. Electron microscopy of soils and sediments: examples. Oxford University Press.

(7) Smart, P., & Tovey, N.K.. 1982. Electron microscopy of soils and sediments: techniques. Oxford University Press.