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MICROMORPHOLOGICAL FEATURES OF SOME YERMOSOLS DEVELOPED ON FLUVIATILE CLASTIC DEPOSITS SOUTHWEST OF THE OMAN MOUNTAINS

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MICROMORPHOLOGICAL FEATURES OF SOME YERMOSOLS DEVELOPED ON FLUVIATILE CLASTIC DEPOSITS SOUTH-WEST OF THE OMAN MOUNTAINS

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ABSTRACT

Bridges, E.M. and Creutzberg, D. 1988. Micromorphological features of some Yermosols developed on fluviatile clastic deposits southwest of the Oman Mountains.

Four soil profiles from Oman were described and classified in the field as Haplic, Calcic, Gypsic and Luvic Yermosols. Micromorphological examination of the surface horizons revealed fine crystalline carbonates organized into ooid-shaped pellets embedded in the groundmass. Dense masses of fine crystalline material with vesicles, former surface crusts, occur throughout the profiles. In calcic horizons a denser fabric of clay, strongly impregnated with fine crystalline carbonates, is characteristic. Gypsum occurs as agglomerates of small crystals between existing grains and large crystals of gypsum completely engulf pre-existing soil minerals. Micromorphological evidence supported the field classification of the Haplic, Calcic and Gypsic profiles, but as argillic features were absent from the thin sections, it is preferable to classify the fourth profile as a calcic rather than a Luvic Yermosol.

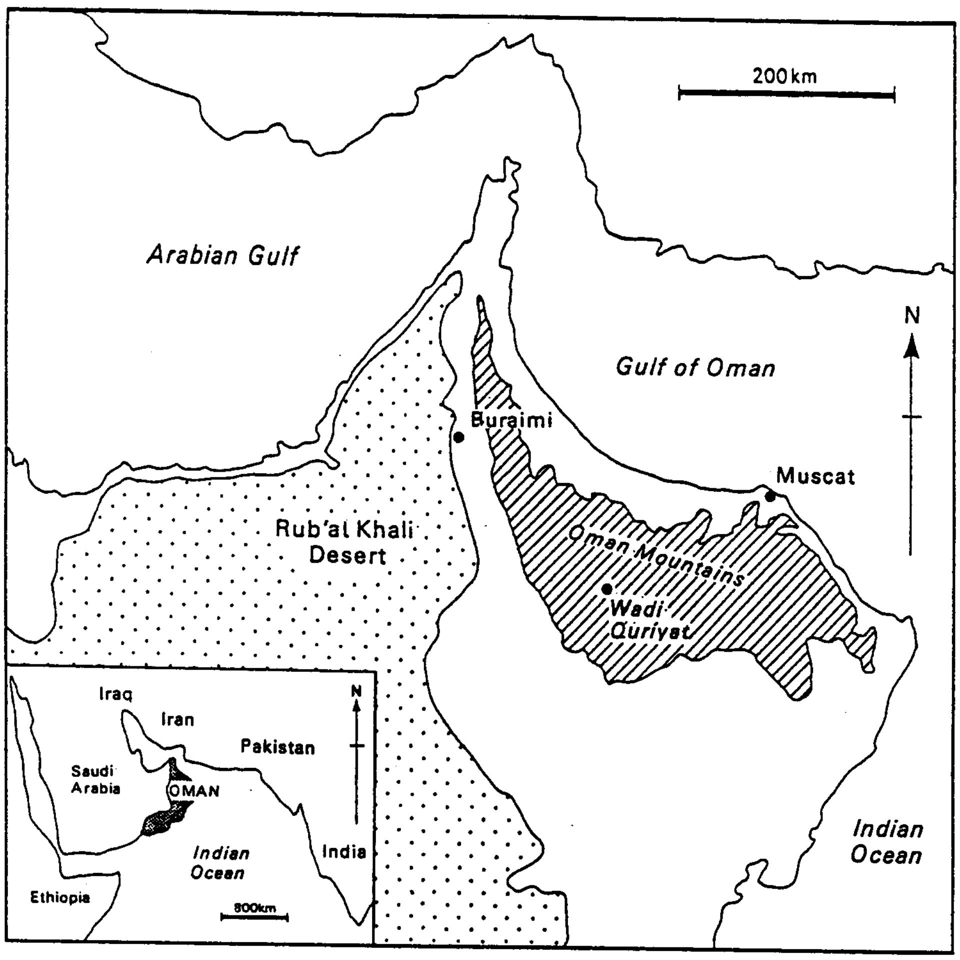
INTRODUCTION

The soils featured in this study were surveyed and sampled during a soil and groundwater survey for the Ministry of Agriculture of the Sultanate of Oman. The field survey was carried out by A.A. Hutcheon and W.B. Kerr for Groundwater Development Consultants (International) Ltd, in association with Sir M. MacDonald and Partners and Hunting Technical Services Ltd. With the active interest of Dr. M. Ramzan, the Agricultural Research and Development Officer for FAO/UNDP in Oman, four soil profiles were obtained which now form part of the collection at the International Soil Reference and Information Centre, Wageningen.

LOCATION AND ENVIRONMENT

The four profiles were described and sampled from two areas, Wadi Quriyat and Buraimi which lie to the west of the Oman Mountains (Fig. 1). The climate of this area is arid, characterized by very hot summers with maximum temperatures of 40-44°C and cool winters with minimum temperatures of 5-7°C. On Jebel Akhdar, the highest part of the Hajar range, where elevation of over 3000 m occur, rainfall may exceed 400 mm but throughout the rest of Oman, precipitation is less than 100-

125 mm. This rainfall occurs only during the winter months (November to April), and the summer precipitation is nil or very slight in amount.



The Oman Mountains are composed of sedimentary rocks of Cretaceous age which have been thrust-faulted with ultrabasic ophiolites in the late Cretaceous and uplifted in the Miocene. In these mountains, mantle rocks of peridotite, crustal gabbros and pillow lavas have been incorporated into nappes with marine shelf carbonates which range in age from Permian to Cretaceous. Thus although the most extensive rocks are limestones and marls, basic igneous materials are also present in the weathering product. Erosion debris from the degradation of the mountains has been carried inland to the south and west to form extensive alluvial fans which have become linked together as a bajada at a height of between 500 m and 750 m above sea level (Tosi, 1975).

The soil survey of potential agricultural land, and hence the location of the soil profiles studied, was on these inland slopes. The interior foothills and plains are up to 80 km wide and lie between the Oman mountains and the sand desert of the Rub' al Khali. The individual alluvial fans are crossed by wadis which have re-worked the coarse clastic deposits laid down earlier. As a result the wadi channels were slightly incised into the surface. Subsequently, at Wadi Quriyat, some of these inactive wadi courses have been infilled with fine-grained sediment from alluvial fans lying north of the present active channels. These fine-grained sediments range in thickness from 50 to 150 cm and form the level surface of the Quriyat and Lajrid plains. The depth to underlying gravels varies considerable as their surface is uneven and in places they protrude through the silts forming ridges on the surface. In the Buraimi district steeply dipping limestones form upstanding Jebels. Erosion of interbedded marls has resulted in intervening basins which have been infilled partially with alluvial sediments. A surface drift of sand has been blown into nebkha, low vegetation-held dunes.

THE SOILS

The four soil profiles under consideration all possess properties which enable them to be classified as Yermosols (FAO, 1974) or Aridisols (Soil Survey Staff, 1987). All formed under an aridic moisture regime and have low levels of organic matter with a silt loam or very fine sandy loam texture. To qualify as Yermosols soils must have subsoil horizons which include altered materials, and/or accumulation of silicate clay, gypsum or carbonates. The soils studied are characterized by a surface crusting 2 to 3 cm thick, a friable or even loose consistency in the surface horizon, light colours, and carbonate enrichment. All soils contain carbonates in excess of 30 percent. From the monoliths and samples it was not possible to make any statement about desert varnish or the presence or absence of sandfilled structural cracks, described by Blume et al. (1984) as typical features of arid soils. Profile OMA.1 has a weak A horizon and a cambic B horizon, so there is a prima facie case for it being a *Haplic Yermosol*, but this needs some explanation as it contains 35 percent calcium carbonate. Although the minimum requirement for a calcic horizon is 15 percent, the material forming this soil is brownish and does not have an increased amount of carbonate in any horizon; the greater part of the carbonate is in the ooid features and fragments of limestone and may be thought of as part of the original sediment and not a pedological accumulation. In profile OMA.2 there is clear field evidence and in the monolith for the presence of a calcic horizon where the carbonate content rises to 70 percent in the B horizon and drops to 30 percent in the C horizon. So, it was classified as a *Calcic Yermosol*. In profile OMA.3 a GYPSIC horizon was recognized in the field by its coarse crystalline nature; analysis subsequently showed it to contain 30 to 40 percent gypsum compared with 20 to 25 percent in the C horizon thus meeting the criteria for a *Gypsic Yermosol*. A striking increase in clay content was observed in the lower horizons of profile OMA.4 as well as the presence of moderately-developed cutans in the B horizon, so the field surveyors designated it a *Luvic Yermosol*.

MICROMORPHOLOGICAL FEATURES

The macrostructure of the upper soil horizons of all four profiles is confirmed in thin section as consisting of very porous, poorly developed subangular aggregates, with crumb structure and single grain where the clay content is lower. The interior of the peds has a spongy microstructure, tending to bridged grain and single grain structure according to clay content. In the surface horizons faunal disturbance is shown by the presence of infilled channels and burrows. There are rare sections of living roots.

Ooid-like grains of calcite (150-200 μm) form the basic mineral components, comprising either crystals or a mass of microcrystalline calcite. The remaining part of the coarse fraction consists of angular and subangular grains of quartz, chalcedony, feldspars with a subordinate amount of accessory minerals. Gravel-sized fragments of limestone and weathered igneous rocks are present throughout the profiles. The fine fraction consists of speckled pale yellow clay, showing a crystallitic b-fabric, the result of the ubiquitous carbonates. Examination of the soil to at least 1 m depth reveals many fragments of former surface crust, densely packed and containing vesicles.

The field evidence suggested different forms of Yermosol based on the nature of the diagnostic subsurface horizons; consequently the findings of this study will be presented under the headings of the cambic, calcic, gypsic and luvic characteristics observed.

Cambic characteristics

Micromorphological examination of the B horizon of the Haplic Yermosol revealed the groundmass to have enaulic and porphyric distribution patterns, aggregated into a blocky structure. These patterns, are associated with strong disturbance by soil fauna which have left vughs, various open and filled channels, burrows and other biopores. Included within the groundmass are many fragments of densely packed, laminated and graded silty crusts containing rounded vesicles. Smaller fragments are usually rounded, but larger elongated fragments mostly have abrupt, broken edges. These fragments occur down to about 100 cm in this profile and between 103 and 111 cm the presence of a set of horizontally disposed crusts suggests a former buried surface. Micromorphological examination confirmed the uniform distribution of carbonates throughout the profile.

Calcic characteristics

In the field survey, the calcic horizon was evident in the profile from its distinctive appearance (pale brown 10YR 6/3 to 7/3) and the content of calcium carbonate, which reaches about 60 percent compared with 30 percent in the horizons above and below. In thin section the macrostructure appears to be moderate, medium blocky with planar voids separating the well-accommodated peds. Within peds, microstructure is massive or channelly. There are only a few larger channels and burrows, some open and others partly infilled, indicating a very low amount of activity by soil fauna.

The groundmass consists of a dense mass of microcrystalline calcite, crystal size rarely exceeding 4 μm, which completely masks the clay present. In rare places, where the calcite is absent and affected by soil fauna, the clay appears to be dominantly isotropic with few acicular and fibrous (1 x 6 μm) birefringent domains, which may be palygorskite. A few isolated channels occur with infillings of coarse silt-size gypsum crystals, other coarse constituents, mainly quartz, are rare.

Gypsic characteristics

Field observations, and an examination of the soil monolith indicate that there is a clear boundary at about 80 cm above which the soil is virtually devoid of gypsum. Below this depth it occurs as clearly recognizable crystals throughout the soil material. Chemical analysis indicates more than 20 percent gypsum. Between 80 to 90 cm, gypsum occurs as large crystalline masses; similar but smaller concretionary masses also occur at greater depth. In thin section gypsum appears in two forms: 1. individual euhedral lenticular crystals (length 250 to 1500 μm, dominant size 500 μm), randomly oriented with large packing voids where other soil constituents are subordinate. Euhedral crystals also occur randomly distributed in the surrounding coarse-textured material. 2. large areas, (a few centimetres) of anhedral interlocking crystals, individual crystals exceeding 5000 μm, often elongate and horizontally parallel to the existing stratified soil materials. Growth of these large anhedral gypsum crystals seems to have engulfed the few quartz and calcite grains present, almost completely filing the voids. They seem to have grown uninhibited by the presence of other soil constituents which are few in these areas. There are also a few concentrations of euhedral celestite crystals in the groundmass and in voids.

Luvic characteristics

Observations made in this study do not support the fieldman's comment that "common moderately developed cutans on ped faces"occur in OMA.4. In the field description, a silt loam A horizon and a very fine sandy loam Bu horizon are described as overlying a silty clay loam Btk horizon with an abrupt boundary. Colour and structure differ, and laboratory analysis indicates that the Bu horizon has about 12 percent and the Btk has 49 percent. In view of the sedimentary environment from which these soils come, there is little doubt that this textural difference results from the original sedimentation. The macrostructure, shown by intersecting planar voids, is moderate to strong blocky, and the interior of peds has a massive to vughy microstructure. Under crossed polarizers the crystallitic b-fabric is similar to that of OMA.1. The clay constituents can be recognized in thin section with common large carbonate nodules (from a few mm to 1 cm) corresponding to the soft $CaCO_3$ seen in the field. No evidence of illuvial clay could be seen on structure faces or void surfaces. Therefore from the micromorphological evidence this profile would be re-classified as a Calcic Yermosol.

CONCLUSIONS

The clayey micromass of all four soils in this study was homogeneously impregnated with fine, microcrystalline calcium carbonate. The related distribution is in part porphyric, in part enaulic and where there was less clay, gefuric. The b-fabric met the requirements for recognition as crystallitic b-fabric, irrespective of the related distribution. Two types occur: the most common consists of clay impregnated with many microcrystalline-sized calcite crystals. using high magnification it could be seen that these crystals were embedded in an isotropic, or very weakly speckled clay. A second type had a massive b-fabric, consisting almost exclusively of carbonates; clayey constituents other than microcrystalline carbonates were extremely difficult to identify as the clay was masked by calcite. A similar b-fabric occurred as coatings and infillings in the underlying gravel of lower 2Ck horizons of OMA.1 and OMA.2. The first type was interpreted as redistributed (in the sense of a cambic horizon) and the second as carbonates accumulated from a source outside the soil profile. Two forms of gypsum accumulation have been observed, but argillic features were absent.

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