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MICROMORPHOLOGICAL STUDY OF CALCRETES IN SOILS OF THE ŽITNÝ OSTROV REGION, SOUTHWESTERN SLOVAKIA

SALEM YASEEN MEJEED

Department of Geochemistry, Faculty of Sciences, Comenius University, 842 15 Bratislava, Slovak Republic

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Abstract: Calcretes have developed in soils of the Žitný ostrov region in response to the mutual interactions between the different prevailing geological and environmental conditions. The evapotranspirative climatic conditions and shallow hydrocarbonatic groundwater play a very significant role in this aspect. Different micromorphological characteristics have been described. The observed microstructures are of massive, intergrain micro-aggregate types, with occasional occurrence of the pellicular type also, in addition to the vughy, intergrain channel, and fissure microstructures. The porosity of these calcretes is dominated by vughs, channels, and planes. There is also a dominance of monic and porphyric related distribution patterns, and rarely of the chitonic type. Different pedogenic features are of special interest, they represent mainly void coating and infilling, in addition to pedofeatures of pseudomorphic, textural and impregnative types, nodules, intercalary crystals, and recrystallization.

Key words: micromorphology, soils, calcretes.

Introduction

Micromorphology is a valuable tool for studying pedogenesis. The carbonates in soils may initially be subdivided into two main groups: primary from the parent rocks, and secondary, developed in the soil itself. The secondary carbonates have been variously referred to as carbonate neoformations (Dobrovolsky 1961), authigenic carbonates (Gile 1965), and pedogenic carbonates (Blokhuis et al. 1968/1969; Sehgal & Stoops 1972). In the course of this study the terms inherited and pedogenic were adopted after Bullock et al. (1985) to describe the primary and secondary carbonates respectively. Soils developed on sedimentary rocks and continental (detrital) sediments may contain carbonates of both categories, and they are, not always easy to distinguish. This is the case in the Žitný ostrov region, as it was outlined by Hraško et al. (1972) and Čurlík (1985). Numerous pedogenic carbonate features have been reported and their genesis in relation to environmental conditions in soils discussed (Dobrovolsky 1961; Gile 1961; Blokhuis et al. 1968/1969; Sehgal & Stoops 1972; Mermut & Arnaud 1981; Mermut & Dasog 1986; Rabenhorst & Wilding 1986a,b,c; Rabenhorst et al. 1991; West et al. 1988a,b; Drees & Wilding 1987). According to Dobrovolsky (1961) there is considerable evidence to show that certain types of carbonate neoformations are formed by supergene processes which can be related to definite landscapes. This is true in the case study of the superaqual landscape of Žitný ostrov, where accumulation of pedogenic carbonates is ascribed to a set of geochemical processes of a carbonatic nature which range from neutral to gley processes (Mejeed 1993).

No detailed systematic micromorphological description of calcretes from soils of Žitný ostrov region has been done up to now. The objective of this work is to throw light on this problem, with special stress on the pedogenic features developed in these soils.

Materials and methods

A detailed description of the geographical location of the study area, prevailing environmental conditions, and general characteristics of the studied soil profiles have been given in the preceeding contribution (Mejeed 1996).

Calcrete samples have been collected mostly by wet sieving of the soil samples. They are mainly of nodular and pedotubular forms (Čurlík & Mejeed 1996). Thin sections were prepared by impregnating these calcrete forms with resin material. The impregnated blocks were sliced and polished thin sections were prepared. Later, a detailed micromorphological description has been carried out according to the Handbook of Bullock et al. (1985).

Results and discussion

Micromorphological description was done on calcretes mainly of nodular and pedotubular forms (Pl. I: Figs. A–C). Micromorphology of the studied samples revealed the presence of many types of microstructures ranging from massive (Pl. II: Fig. A) to intergrain micro-aggregate (Pl. II: Figs. B, C) structures, which are equivalent to the mudstone to wackstone and packstone fabrics, respectively, of Dunham (1962), with more abundance of the intergrain micro-aggregate type. Occasionally, the pellicular type is also represented (Pl. III: Fig. A). This occurs in the case of the simple microstructures which are related to the coarse and fine material. In addition, other microstructures which are based on void patterns are also represented. These occur frequently as vughy structure (Pl. III: Fig. B), intergrain channel structure (Pl. III: Fig. C), and sometimes as the fissure type (Pl. IV: Fig. A).

Accordingly, the porosity of the studied samples is dominated by vughs, channels, and planes. According to Bullock

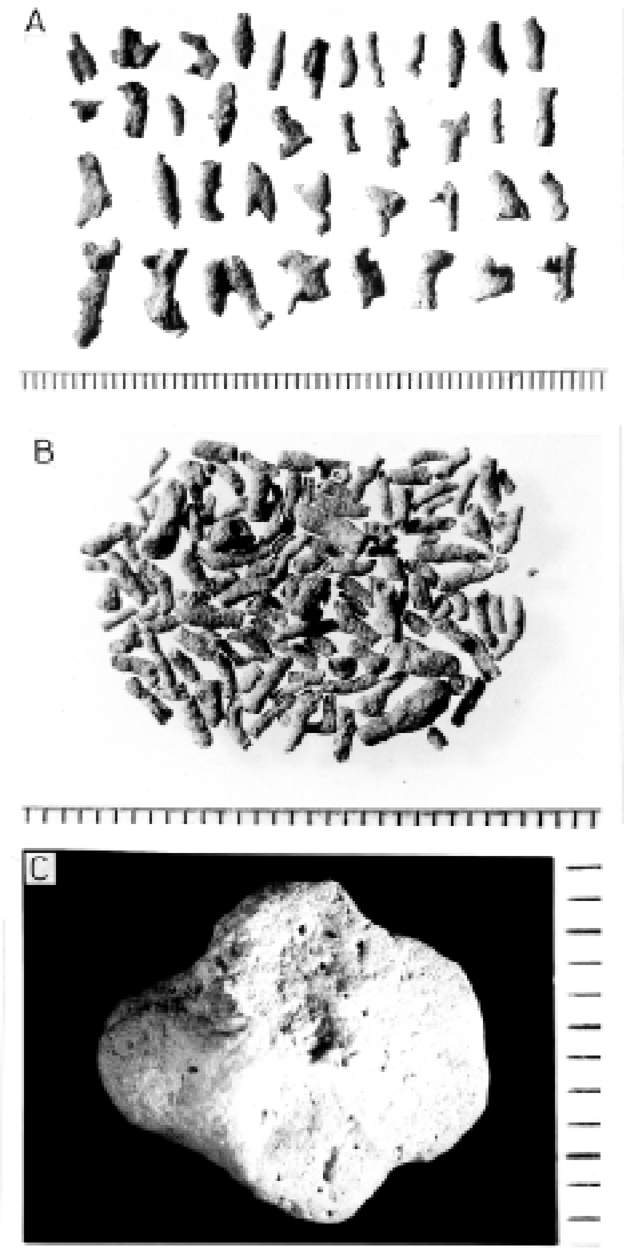

Plate I: **Fig. A:** Pedotubular calcrete (rhizolith structure of root-casts type). Scale in mm. **Fig. B:** Pedotubular calcrete (rhizolith structure of root-tubles type). Scale in mm. **Fig. C:** Irregular nodule containing some root moulds. Scale in cm.

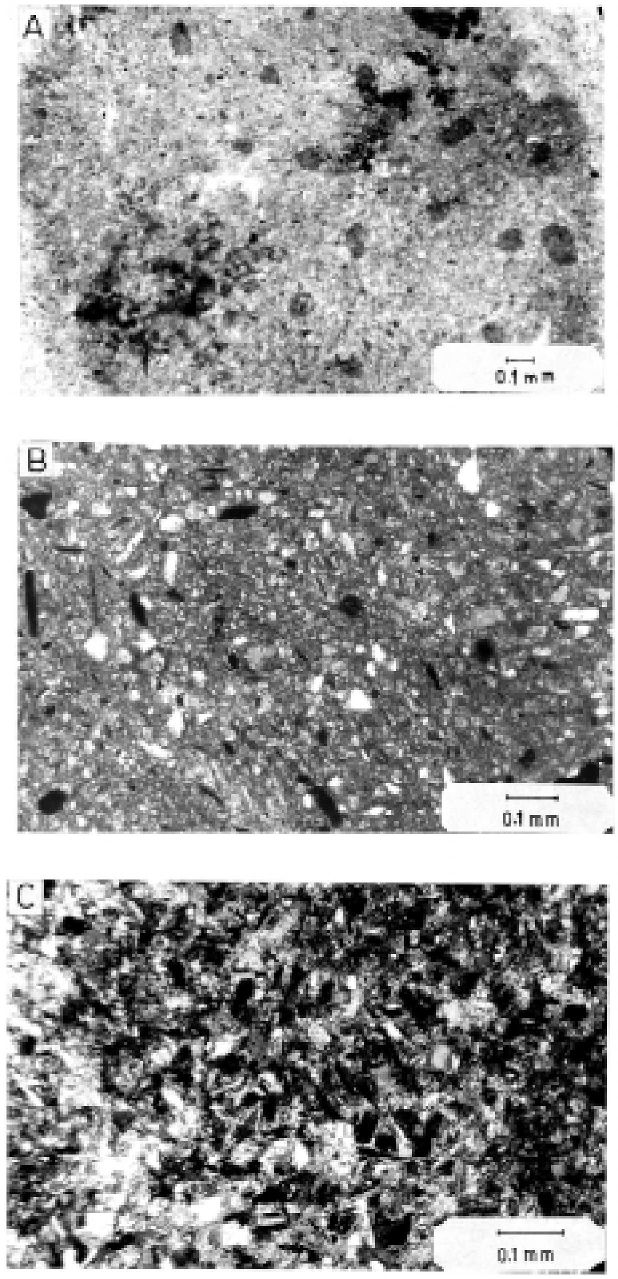

Plate II: Fig. A: Massive microstructure with monic related distribution pattern. Micritic groundmass is impregnated by homogeneous patches of iron oxides. Dark patches mostly represent manganese oxides. XPL. **Fig. B:** Intergrain micro-aggregate microstructure with open porphyric related distribution pattern. The coarse fraction is randomely distributed and consists mainly of mica (biotite and muscovite), quartz, and feldspars. XPL. **Fig. C:** Intergrain micro-aggregate microstructure with close porphyric related distribution pattern. The coarse fraction is randomly distributed and consists mainly of mica (biotite and muscovite), quartz, feldspars, carbonates, and rock fragments. XPL.

et al. (1985). The vughs are spherical to elongated, irregular and not normally interconnected to voids of comparable size. Channels are elongated, cylindrical or arched, with regular conformation, usually smoothed wall and a uniform cross section over much of their length. Planes are designated according to the ratio of the principal axes.

The coarse/fine (c/f) limit is set at 10 µm. This implies that materials less than 10 µm are considered fine components, and materials greater than 10 µm are coarse components. In this work the c/f ratio, and at the same time the abundance of the coarse materials were only relatively estimated. Hence, generally for those samples showing massive microstructure, there is only dominance of the fine material and lack of the coarse material (Pl. II: Fig. A). In samples

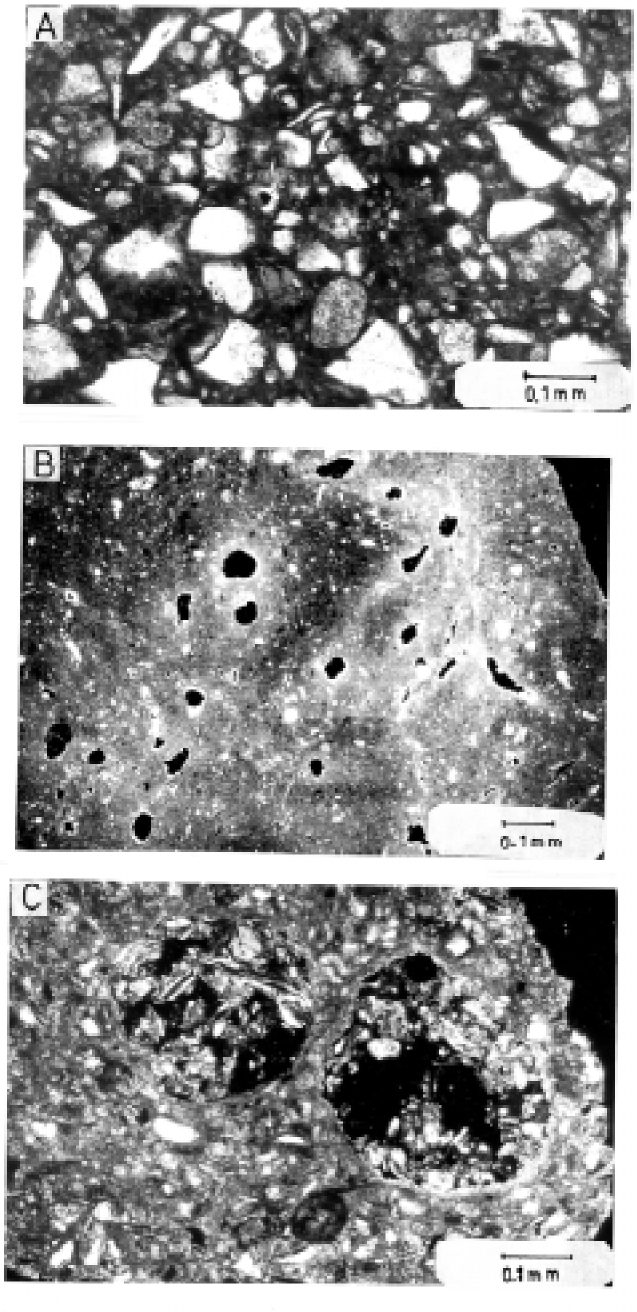

Plate III: Fig. A: Intergrain micro-aggregate to pellicular micro-structure with close porphyric to chitonic related distribution pattern.The coarse mineral grains are randomely distributed. Patches of microsparite are distributed within the micritic groundmass. PPL. **Fig. B:** Vughy to massive microstructure. Pedofeatures are microcalcitic coating of voids, dense complete and incomplete infilling of voids. Micritic groundmass is inhomogeneously impregnated with iron oxides. XPL. **Fig. C:** Intergrain channel microstructure. Channels after roots show loose discontinuous infilling with soil material (textural pedofeature). The channel on the right side shows compound pedofeature resulting from association of infilling with microcalcitic coating (crystalline pedofeature). XPL.

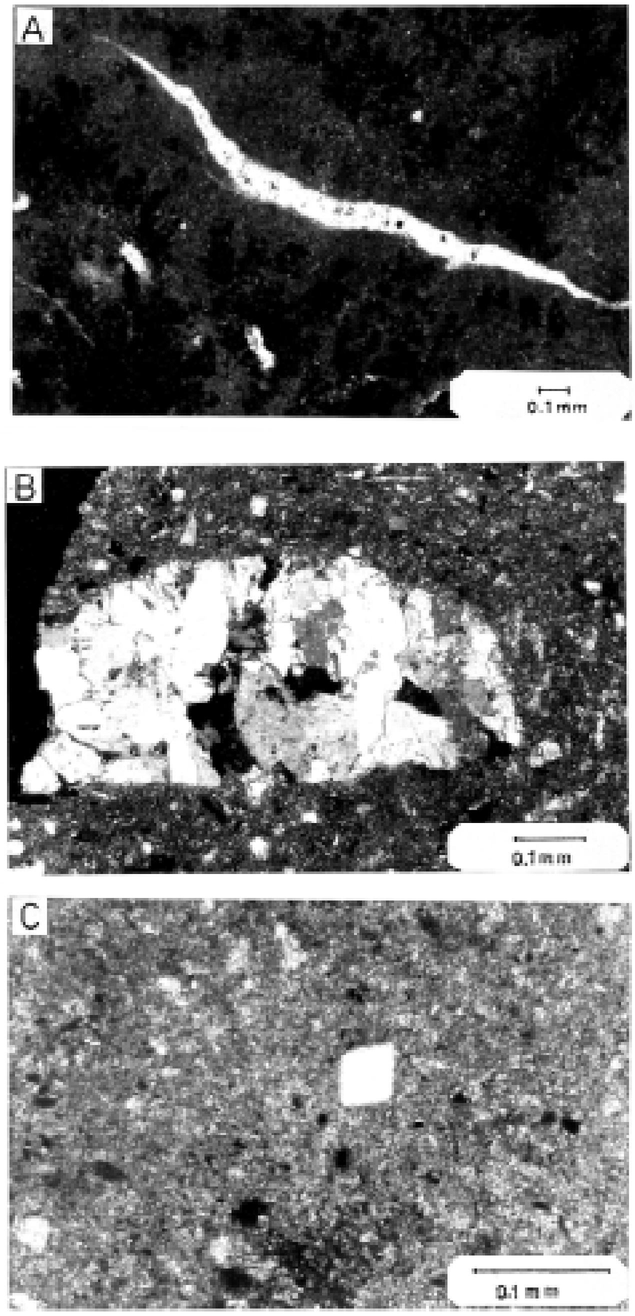

Plate IV: Fig. A: Fissure microstructure with a pedofeature of dense complete drusy calcite infilling of planar void. Microsparitic dense complete infilling of some vughs is also visible.The micritic groundmass is inhomogeneously impregnated with iron oxides. XPL. **Fig. B:** Dense complete drusy calcite infilling of channel. XPL. **Fig. C:** Rhombic calcite crystal embedded in micrite giving typical open porphyric related distribution pattern. XPL.

showing intergrain micro-aggregate structure, this ratio may range from 1 : 2 (Pl. II: Fig. B) to 1 : 1 (Pl. II: Fig. C). Qualitatively the coarse components consist substantially of quartz, mica (biotite and muscovite), feldspars (orthoclase, microcline, perthitic feldspars, plagioclase), detrital carbonates (inherited), as well as some chlorite, amphiboles, and rock fragments (Pl. II: Figs. B, C; Pl. III: Fig. A). These minerals are randomly distributed within the fine groundmass and mostly have subhedral to anhedral shapes. In addition to single mineral grains, inorganic residues of biological origin are occasionally represented among the coarse fraction. These are mollusc shells consisting mainly of calcium carbonate (aragonite or calcite) and are thus characterized by high interference colours. The fine materials consist of carbonate mud (micrite), occasionally moderately impregnated with iron oxides, and sometimes with manganese oxides (Pl. II: Fig. A; Pl. III: Fig. B; Pl. IV: Fig. A; Pl. V: Fig A). This composition of the fine groundmass is reflected in its b-fabric which usually shows a strongly crystallitic fabric characterized by the presence of small birefringent crystallites (calcite).

The represented related distribution patterns (RDP) are in line with the observed microstructures in the studied samples. Here there is a dominance of monic (Pl. II: Fig. A), and porphyric, both open (Pl. II: Fig. B) and closed (Pl. II: Fig. C) related distribution patterns. Occasionally the chitonic type was also observed (Pl. III: Fig. A). The porphyric RDP is characterized by coarse materials embedded in the dense groundmass of fine material. The chitonic RDP is best described by the presence of fine materials as thin incomplete coatings on coarse materials.

The concept of pedofeatures was introduced by Brewer & Sleeman (1960 in Bullock et al. 1985) for all units resulting from past or present pedological processes.

Many types of pedofeatures were observed in this study especially those of crystalline type. They occur mainly as microcalcitic void coatings of typic and crescent type (Pl. III: Fig. B) and are usually developed on vugh and channel walls. Microsparitic and drusy calcite infilling of vughs (Pl. III: Fig. B), channels (Pl. IV: Fig. B), and planes (Pl. IV: Fig. A) represent the further noted crystalline pedogenic features. They occur as both dense complete and dense incomplete infilling. Another type of void infilling which was also observed is the loose discontinuous infilling of channels by soil material akin to the groundmass material (Pl. III: Fig. C). This type of pedofeature represents a textural type according to the classification of Bullock et al. (1985).

The other interesting crystalline pedofeatures belong to the pseudomorphic type according to Bullock et al. (1985). They are usually composed only of crystalline material pseudomorphosing, partially or completely, plant tissues, faunal remains or rock or soil fabric. In the case study, calcite is completely pseudomorphosing plant roots and preserving their cellular structure (Pl. V: Figs. B, C). This is equivalent to the "petrification" process (i.e. calcification) of Klappa (1980). It results from the filling of the actual root zone by pedogenic carbonate during the life of the plant and hence the cellular structure of the root can be seen clearly in the resulting carbonate. Sometimes, an envelope of micritic calcite (tubule) is formed around the root.

The amorphous pedofeature of impregnative type (Bullock et al. 1985) represents another prominent pedofeature in this study. It is formed by amorphous material (iron oxides or less common manganese oxides) impregnating the nodules fabric. These nodules are moderately impregnated as the original material (carbonates) which has been impregnated by the iron oxides is common and clearly identifiable. Impregnation could be of homogeneous central type, with iron oxides uniformly impregnating the central part of the nodules leaving free-iron oxides peripheral rims (Pl. V: Fig. A), or sometimes exists as homogeneous patches of iron oxides (Pl. II: Fig. A), or inhomogeneous impregnation (Pl. III: Fig. B). These pedofeatures are ascribed to the oxidizing carbonatic processes that prevail in some parts of Žitný ostrov, which are also reflected in the morphology of soil profiles where special horizons have been developed of oxidizing (bright brown mottling) phenomena.

The above mentioned pedofeatures represent simple pedofeatures composed of a single component or characterized

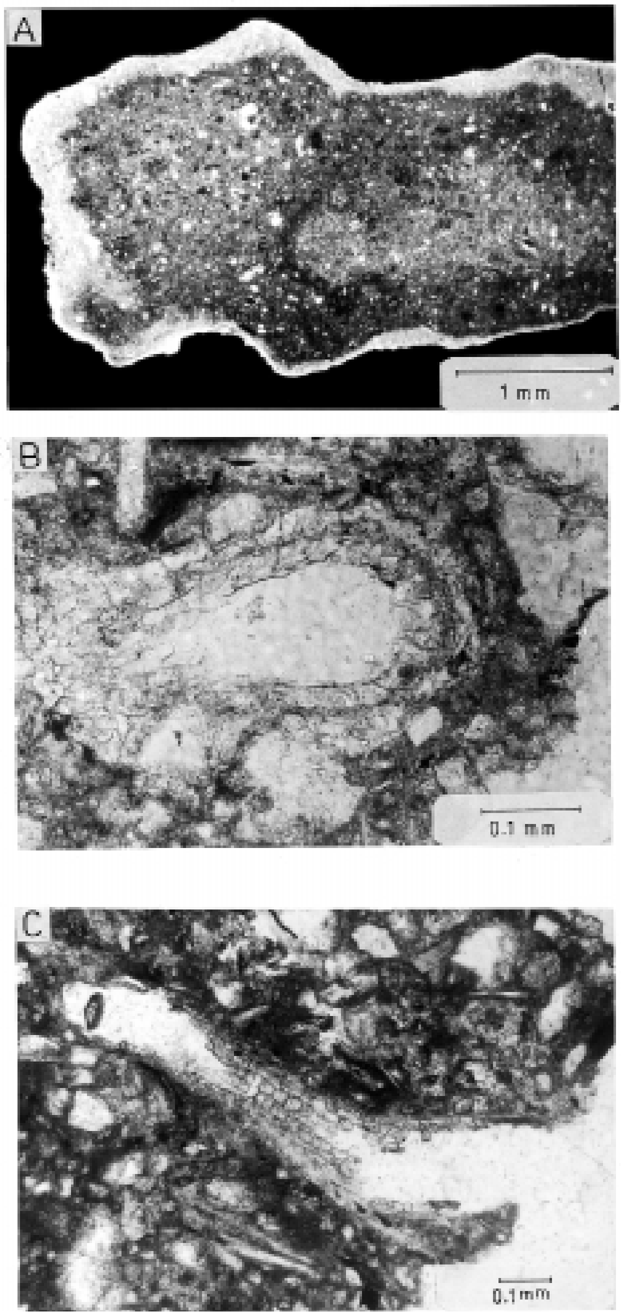

Plate V: Fig. A: Part of nodule with massive microstructure and almost homogeneous central impregnation. XPL. **Fig. B:** Petrified root and consequent preservation of its cellular structure. PPL. **Fig. C:** Petrified root. PPL.

by an internal fabric. Frequently, pedofeatures are a composite mixture of two or even more fabric units, in which case they are termed "compound" (Bullock et al. 1985). They are important because they often indicate a change in environment. Such compound pedofeatures were occasionally observable in this study. For example, an association between channel-microcalcitic coating (crystalline pedofeature) and channel infilling with soil material (textural pedofeature) results in a further compound (Pl. III: Fig. C).

Other observed pedofeatures are those which are not related to voids, grains and aggregates (Bullock et al. 1985) such as nodules and crystals. We should stress that the micromorphological description in this study was done on nodules already separated from soil samples, and hence they should represent one of the main pedofeatures developed in the soils of Žitný ostrov. Observed nodules or glaebules (Pl. I: Fig. C) mostly have an undifferentiated internal fabric (structureless), of course are calcareous and sometimes impregnated with Fe and Mn oxides, distinct because they could be easily removed from the soil mass, and are mostly irregular in shape. Wright & Tucker (1991) have considered diffusion of carbonate to certain sites as a critical factor in nodule formation, which is usually followed by precipitation and displacive growth, for most nodules contain very little of the original matrix.

Another characteristic pedofeature is the presence of intercalary rhombic calcite crystals with well developed surfaces, i.e. euhedral (Pl. IV: Fig. C). They are embedded in the carbonatic fine groundmass and frequently show typical porphyric related distribution pattern. These isolated crystals are considered to be crystalline pedofeatures by Bullock et al. (1985). Such rhombic calcites are common in recent subaerial carbonates and have been described from soils and weathering profiles (Folk 1971, 1974; Chafetz & Butler 1980; Wright 1982). Folk & Land (1975) considered that in very dilute waters, without competing cations such as Na^+ and K^+, calcite forms rhombohedra 2–10 μm in size. The rhombic form of the calcite crystals has been attributed to formation in the fresh water realm under conditions of slow precipitation (Folk 1971, 1974).

A recrystallization process may probably proceed in the studied soils, where micrite is recrystallized to microsparitic calcite which is usually distributed as patches within the micritic groundmass (Pl. III: Fig. A). However, this observation is limited to very few samples. The literature on modern and ancient calcretes contain many references to recrystallization (Retallack & Wright 1990). Sehgal & Stoops (1972) proposed that the zones of coarse, granular calcite in the soils of Punjab are formed by recrystallization of microcrystalline calcite.

Conclusions

From the previous discussion it can be concluded that the following forms of pedogenic carbonates are forming in the soils of Žitný ostrov:

— Accumulation in the fine groundmass (micritic).

— Void coating, commonly associated with vughs and channels.

— Void infilling associated with vughs, channels, and planes.

— Intercalary rhombic calcite crystals.

— As products of recrystallization of micrite resulting in microsparitic calcite within micrite.

— Pseudomorphosing of plant root (calcification).

Among these forms the micritic ones are the most abundant followed by void coating and infilling, while other forms are much less frequent.

Such carbonate forms are ascribed to the epigenetic geochemical carbonatic processes prevailing in the area. These processes are mainly neutral, but they become oxidizing at some places as is evident from iron oxide-impregnations, and elsewhere they become gley leading to remobilization of iron oxides as is illustrated by some iron oxide-impregnated nodules with iron oxide-free peripheries. These processes are also shown by the soil morphology, where different horizons have been developed, calcic, oxidizing (bright brown mottling), and gley/reducing (grey mottling). Thus, both micromorphological and morphological evidences indicate the influence of groundwater on soil cover in Žitný ostrov which results in consequent formation of calcretes and other types of duricrusts (ferricretes and manganocretes).

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