УДК 631.4

CURRENT TRENDS IN SOIL MICROMORPHOLOGY: BIBLIOMETRIC APPROACH

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The analysis of publications has shown that the period of intensive development of several spheres in micromorphology in the second half of the XX century was followed by a period when micromorphology became more required in applied research. Addressing micromorphology for solving pedogenetic and taxonomic questions became reduced both in Russia and in the world. Further progress of traditional micromorphology in Russia is expected owing to application of sophisticated equipment, participation in hierarchical morphogenetic studies, as well as to the possibility for students and professionals to work with a "database" – collection of thin sections representing a broad array of soils. This work is initiated at V.V. Dokuchaev Soil Science Institute, where many thin sections are already accumulated, and most specialists worked and are now working there.

Key words: micromorphology, bibliometric analysis, prospects of micromorphology development.

DOI: 10.19047/0136-1694-2016-86-17-27

INTRODUCTION

Beginning with the 1940-ies, soil scientists started using the polarizing microscope for soil investigations in thin section mostly at magnifications 20x…100x. These intervals enlarged with time, new technologies became complementary to the optical ones, which opened new horizons for research. The traditional micromorphology found its due place in the field of hierarchical morphogenetic analysis.

Unlike many other scientific branches, micromorphology has it birthday: year of 1938, when Walter von Kubiëna published his famous book "Micropedology" (Kubiëna, 1938). In this fundamental monograph, he formulated the concept of genetic micromorphology, declared the methodological principles, and proposed technical means for

investigating mineral, organic and microbiological soil ingredients; he developed a special terminology and made micromorphological descriptions of many soils indicating the pedogenetic processes responsible for the formation of micromorphological properties. Further development of micromorphology in the USSR and Russia continued within the scope of ideas and methodology of W. Kubiëna.

Just this traditional genetic micromorphology complemented by more recent morphographic ideas is the object of our review.

A substantial progress in micromorphology was recorded in western countries and USSR in the 1960–1980-ies – years when theory, methodology, technical facilities were quickly developing. This is testified by abundant publications including the international "Handbook for Soil Thin Sections Description" (1985), proceedings of international workshops in Germany (1958), the Netherlands (1964), Poland (1969), Canada (1973), Spain (1977), and Great Britain (1981). In our country, the advances of micromorphology are manifested by numerous articles in journals, monographs, manuals, special collections of papers, and inclusion of micromorphological descriptions in monographs on soil genesis and geography, as well as in PhD theses. In 1980, the first All-Union conference was organized in Kharkov; the International workshop (the only one in Russia) took place in Moscow in 1996, in Lomonosov State University, where a very important event happened: E.A. Yarilova received the highest International award of micromorphologists – the Kubiëna Medal.

OBJECTS AND RESULTS

The analysis of information concerning regular workshops on soil micromorphology during the last 20 years has shown a certain decrease in the number of research works in this area, although micromorphology remains required for many purposes. The number of countries participating in these workshops is rather stable: 20–25, whereas the number of presentations decreased from 160–170 in 1980–1990-ies to 100–120 in 2004–2012.

A bibliometric analysis of the "fabric" of soil micromorphological research in the 20th century" was presented by the Belgian micromorphologist Georges Stoops, the informal leader of micromorphologists nowadays, at the last workshop in Spain (Stoops, 2012). It was based on processing ca.4000 publications, and the trends revealed are

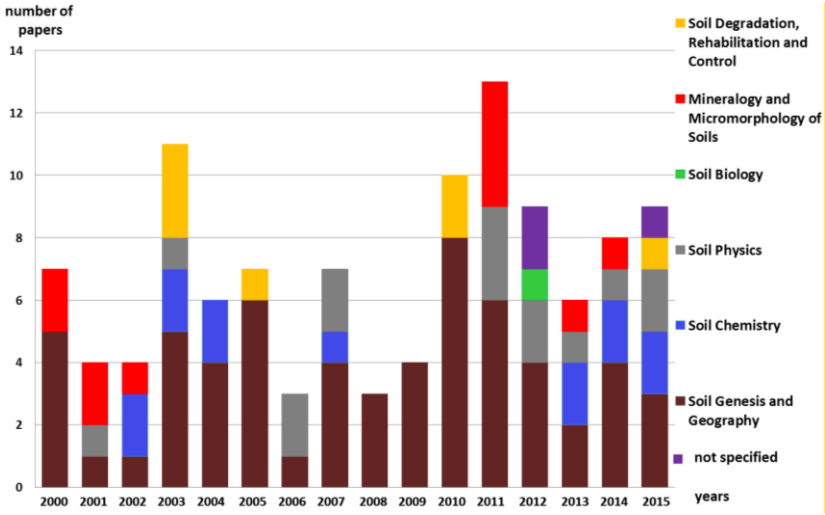
as follows. In the second half of the XX century, micromorphologists were mostly concerned with proving the importance of their science and its advantages over other methods for pedology, application of micromorphology to soil classification, and special terminology, which was discussed most actively. Very similar were the trends in micromorphology development in the USSR/Russia. Stoops has shown that in the XXI century, micromorphology acquired an obviously applied character, and is broadly involved in studies on archeology, Quaternary geology, to a lesser extent – in agriculture; in pedogenetic research micromorphology is used in a "routine" manner.

Following Stoops's approach, we have analyzed publications in several aspects.

Primarily, we have assessed the number of papers in "Pochvovedenie" journal – one of major sources of information on soils in our country.

Micromorphological papers were accounted for the period of 2000–2015. These were papers containing general descriptions of microfabric of soils (horizons), as well as of individual soil components, mostly – neoformations (pedofeatures). The share of such papers was low: it did not exceed 3–5%, and they were unevenly distributed among years: 38 for 2000–2005, 31 for 2006–2010, and 45 in 2011–2015; hence, there is a trend of a weak increase in the number of publications in the last 5 years.

The next step was the assessment of the distribution of papers with micromorphological information among the traditional sections of the journal (Fig). The result was quite expectable: more than a half (52 papers) were published in the section "Soil Genesis and Geography", paleopedological papers are included there as well; the section "Mineralogy and Micromorphology of Soils" is two times poorer (25); the sections "Soil Chemistry" and "Soil Physics" contain 11 and 14 such papers, respectively; 4 papers refer to "Soil Degradation, Rehabilitation and Control"; 2 – "Soil Biology". The latter is especially distressing, because micromorphology accumulated considerable knowledge on soil fauna and manifestations of its activity, as well as on plant residues transformations, which are part of humus status diagnostic, and indicative of environmental situation; therefore, the collaboration with soil biologists might be very efficient.



Distribution of papers containing micromorphological data among the traditional sections of "Pochvovedenie" journal in 2000–2015. Conventions: Soil Degradation, Rehabilitation and Control, Mineralogy and Micromorphology of Soils, Soil Biology, Soil Physics, Soil Chemistry, Soil Genesis and Geography, not specified.

The geography of micromorphological research is broad both in Russia and in the World: Ukraine, Mongolia, Turkmenia, Armenia, Kazakhstan, Uzbekistan, Mexico, USA, Argentina, Chile, Yemen, Spain, Arctic and Antarctic.

The information collected for "Pochvovedenie" journal represents the status of micromorphology in the field of soil science in broad outline, while trends in its own development are identified by analyzing the titles and abstracts in proceedings of national conferences and in special collections. Rather tentatively, the topics were categorized in 9 groups (Table).

The group "Genesis of soils and soil-forming processes" comprises publications on micromorphological diagnostic of mechanisms, basically on the level of elementary pedogenic processes (EPP, such as illuviation or partluvation). In the group "Soils", micromorphological descriptions of soil types, mostly natural, and their "central images" are common, along with agrogenic soils, their individual features, or micromorphological properties of their plow horizons; technogenic soils

Themes of micromorphological studies in materials of workshops

Place of workshops, years	Study objects								
	genesis, processes	theory	types of natural soils	agrosoils	technosoils	paleosols, evolution	soil properties	methods	experiments
Kharkov, 1981	5	2	16	7	2	2	7	0	0
Tartu, 1983	13	6	20	10	2	8	21	6	1
Pushchino, 1986	17	4	7	16	7	10	19	4	1
Moscow, 1996	9/10*	8/4	9/13	11/12	6/2	11/7	13/20	5/21	0/4
Moscow, 2016**	7	3	5	1	4	7	8	1	3

* Above the line – data on domestic reports; under the line – foreign reports.
** Abstracts, submitted to the current conference "Morphology of soils: from macro- to micro-level", 14–16 December, 2016.

are also included. Paleosols were separated in a special group together with micromorphological diagnostics of evolution phenomena. In the group "Properties", characteristics of fabric elements are considered, with the priority of pedofeatures, and this group is the most voluminous. Presumably, this block is "the most micromorphological" because the special micromorphological tools and approaches are most comprehensively realized there. It is followed by the group with soil types displaying a distinct trend of decrease in number with time; an opposite trend is very clear – growth of interest to paleosols, and to the technogenic ones, although the number of publications on the latter soils is not yet large. Very scarce are conceptual and methodological issues, and the contrast between home and foreign sources is prominent; western micromorphologists pay much attention to the technology of thin sections preparation and to methods of electron microscopy–submicrosopy. It is worth to note that the first monograph on the latter subject was published in the USSR in the last century (Dobrovol'skiy, Shoba, 1978).

There were many monographs in 1980–1990-ies concerning micromorphology of soils of natural zones, which was always traditional for Russian pedology (Gerasimova et al., 1996); in more detail, tundra and taiga soils of European Russia were described (Rusanova, 1987), paleosols of Europe (Morozova, 1981), diagnostic of pedogenesis in diverse soils (Romashkevich, Gerasimova, 1982), frozen sediments (Micomorphology of frozen sediments, 1988); even individual pedofeatures were objects of monographs – iron-manganic nodules in the Far-East soils (Roslikova, 1996), more recently, coatings in soddy-podzolic soils (Bronnikova, Targulian, 2005).

This array of monographs was preceded by publications concerning special terminology (1974, 1975, 1983), guides and manuals: Parfenova, Yarilova, 1962, 1972, 1977; Dobrovol'skiy, 1974; Methodological guide ..., 1983; Scheme of description .., 1975; Gagarina, 2004. Of special interest were thematic collections of papers: the first one (Micromorphological method..., 1966) was advertising the micromorphological method and its possible applications; then followed diagnostic of soil-forming processes (Micromorphological diagnostics..., 1983), micromorphology of some specific or weakly studied soils and sediments (Micromorphology of soils and sediments..., 1973), humanly modified soils (Micromorphology of anthropogenically.., 1988), and some applications (Mineralogical composition and micromorphology .., 1990).

Thus, by the beginning of the XXI century, the traditional micromorphology accumulated a considerable volume of data on recent soils, and much less knowledge on paleosols, on the diagnostic of EPP; it became advanced in the world of ideas on the origin of microfabric elements and their geographical patterns.

DISCUSSION AND PROSPECTS

Traditional micromorphology in the beginning of the XXI century. At present in *Russia*, as compared with the second half of the last century, there is a trend of decreasing the number of "descriptive" papers (soil types), more active addressing to analytical materials, and to the diagnostic of EPP. We may guess that the period of accumulation of empirical data is more or less accomplished, main principles and objectives became rather obvious, and links with other fields of soil science were formed. An important function of micromorphology

in the first decade of the new century and further, according to W. Blum, Secretary General of the ISSS, is the maintenance of bonds among separate spheres of soil science: physics, biology, mineralogy, etc.; in other words, micromorphology is functioning as an "integrating tool" (Blum, 2008).

Addressing the micromorphological diagnostic of pedogenetic processes may be regarded as a consequence or continuation of the preceding period, when data on microfabrics of many soil types had been stored. Other reasons of the interest to the processes may be the fundamental monograph of the Institute of Geography, RAS "Elementary Pedogenetic Processes" (1992), along with the development of studies on agrogenic and technogenic soils: search of natural and particular human-induced processes in them identified (discriminated) by means of micromorphology. This issue seems to be implemented in the proposals to apply micromorphology as a diagnostic tool for soil classification (Soil micromorphology…, 1985; Wilding, 1990; Gerasimova et al., 1997). However, it has a serious limitation for the recent classification of soils of Russia (2004, 2008), since it is oriented on soil identification in the field, and laboratory data are weakly used there. The only soil property that preserved its importance either at the macromorphological, or at micromorphological level, are coatings differentiating the clay-illuvial (BI) and textural (BT) horizons.

In *western countries*, despite rather pessimistic results of the bibliometric analysis of G. Stoops, a huge work is being done now in the field of traditional micromorphology by him and colleagues, and Russian micromorphologists are also involved in it. One aspect of this work is unification and updating of terminology. It is worth reminding that two approaches exist in micromorphological terminology: descriptive-genetic of Kubiëna and morphographic one of Brewer (Brewer, 1964; Glossary of soil micromorphology.., 1979), that were successfully harmonized in the International guide (Handbook for Soil Thin Sections Description, 1985). In order to continue this work and correlate the terminology in different countries (languages), G. Stoops prepared a list of 220 important terms (basing on his "Guide…", 2003) and downloaded it at the Internet site in 2011 (List of …, 2011, http://www.plr.ugent.be/micromorphology_news.html). The terms were translated in 16 languages including Russian; this system of terms became now a standard for descriptions and is used in International

journals (Gerasimova et al., 2011). Regrettably, the majority of Russian authors describe their objects in terms of the 1960–1970-ies.

A more noteworthy event in the field of traditional micromorphology was the appearance in 2010 of a beautiful book written by 46 specialists from 15 countries initiated and edited by G. Stoops, V. Marcelino, and F. Mees; it has a rather unusual and meaningful title: "Interpretation of Micromorphological Features of Soils and Regoliths". The book has 720 pages, many high-quality photographs, and covers a very broad spectrum of subjects: descriptions of soil-forming mechanisms, characteristics of separate fabric elements, archeological objects, diagnostic horizons, anthropogenic modifications of soil properties, etc. for many soils of the world. The emphasis in the book is put on interpreting the microfabric elements indicative of the processes responsible for formation of individual soil and/or lithogenic ingredients of the soil material. In total, many current problems and topics are concerned in the book. We assume that in terms of conceptual background and scope, the book reminds Kubiëna's "Micropedology". Nowadays, a second edition is under preparation. The approaches and information in this monograph will hopefully enable micromorphologists to contribute to the main destination of traditional micromorphology – to receive real information, specific and complementary, on soils, to improve and update the results of micromorphological observations. To achieve these goals, very promising may be integration of optical microscopy, electronic submicroscopy, microchemical analysis, quantitative methods of image analysis.

Prospects of micromorphology development. At present, the main trends outlined by L. Wilding (1990) as promising ones, attract more attention, namely: micromorphological method in landscape and environmental studies, insight into the soil cover composition and relationships between its ingredients, agriculture, paleopedology and archeology.

The following objectives for traditional micromorphology should be enumerated within the scope of these main trends:

– developing criteria for assessing soil quality, degree of soil degradation, and stable soil functioning in different land-use systems;

– continuation of traditional pedogenetic studies, including those of soil processes, weathering manifestations using optical and electronic microscopy and microanalysis;

– revealing polygenetic features testifying to recent or former changes in climate and vegetation;

– looking for diagnostic markers of extreme situations in soils, catastrophic events including the technogenic catastrophes;

– developing archeological and geoarcheological micropedology with the purpose to acquire knowledge on paleoenvironments, former processes in soils, on artifacts and on the imprints of ancient people activities;

– recognizing soil – biota interactions (biofilms, roots, micro- and mesofauna).

To provide the development of micromorphology, it is highly important to have an updated collection of thin sections supplied with diverse information, both factual and bibliographic. The best chances for a success of such work exist in V.V. Dokuchaev Soil Science Institute, where this work already started. A database is being organized from materials accumulated in the Institute during more than half-century in the Laboratory of Soil Mineralogy and Micromorphology. The majority of thin sections were made by E.F. Mochalova, and their quality was always high. Nowadays, new facilities are used for thin sections preparation, taking pictures, applying computer software for thin sections processing; new microscopes with sophisticated equipment are used, such as "Olympus BX51" with "Olympus DP26" camera, and the software "Olympus Stream Basic".

These modern devices provide high-quality imaging in a dynamic scaling regime, enable specialists to perform the initial processing of images, measurements and to develop a flexible database.

The extension and perfection of research methods do not exclude their interaction with traditional micromorphology. Primarily, this means addressing to electronic microscopes and microtomographs, which proved to be especially efficient for studying pedogenesis in extremely cold (Arctic and Antarctic) and extremely hot deserts (Gobi and Mojave). Application of X-ray microtomography for assessing the structure status of soils, quantification of pore space and characterizing diverse pedofeatures (salts, Fe–Mn nodules) seems promising.

On the other hand, traditional micromorphology remains an expedient and important stage in the hierarchical morphogenetic research, and the transition from mesomorphology to micromorphology or their interface is still a weakly explored and promising sphere for applying efforts of micromorphologists.

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For citation: Lebedeva M.P., Kovda I. V., Gerasimova M. I., Dostovalova E. V. Current trends in soil micromorphology: bibliometric approach, *Byulleten Pochvennogo instituta im. V.V. Dokuchaeva*, 2016, Vol. 86, pp. 17-27. doi: 10.19047/0136-1694-2016-86-17-27