УДК 631.4

SOIL MORPHOLOGY: NEW CHALLENGES AND OPPORTUNITIES

A. L. Ivanov

Dokuchaev Soil Science Institute, Pyzhevskiy per. 7, Moscow 119017, Russia
e-mail: ivanov_al@esoil.ru

DOI: 10.19047/0136-1694-2016-86-3-7

The present issue of the Byulleten Pochvennogo instituta im. V.V. Dokuchaeva comprises articles from the conference "Soil morphology: from macro- to submicro-scale" held for the first time in Russia and worldwide in 2016. Soil morphology is a branch of soil science that originated in Russia, with its fundamental base established by S.A. Zakharov (in the 1920s) and actively developed by researchers in the V.V. Dokuchaev Soil Science Institute since the moment of its foundation (in 1927).

Currently, the three main goals of soil morphological research are formulated as follows:

– creation of a basis for the adequate diagnostics and classification of soils in substantive-genetic systems;

– objective substantiation of data of chemical analyses with the use of obtained information for various purposes;

– development of multi-scale representations of soil morphology on the basis of meso-, micro- and submicromorphological studies.

It should be noted that traditional morphological descriptions performed by soil scientists often turn out to be insufficiently complete for the purposes of soil diagnostics and create problems in identifying soil horizons by their features, position in the soil profile and shapes of boundaries. The choice of diagnostically significant soil features is important.

A pressing challenge for Russian researchers is the creation of a new modern guidebook for field description of soils with an emphasis on their morphological features, analytical properties (including express determinations) and soil-forming factors as a tool for the diagnostics of soil horizons within the framework of the new Russian soil classification system, as an analogue of the FAO Guidelines for Soil De-

scription (2006) for the international soil classification. Conducting such work in the Dokuchaev Soil Science Institute will be a continuation of its traditions.

The conference has shown that traditional soil micromorphological analysis is a necessary and important stage of a hierarchical morphogenetic study of soils. At the beginning of the 21st century, micromorphology links separate branches of soil science (soil physics, biology, mineralogy, etc.) and serves as an "integration tool" as argued by Prof. Blum, the former Secretary General of the International Union of Soil Sciences (Blum, 2008).

A collective monograph under the unusual title for a western publication – "Interpretation of micromorphological features of soils and regoliths" (2010) – was an important event in the field of traditional micromorphology. The ideology of this book is broadly similar to that of the famous book "Micropedology" (Kubiena, 1938). This approach should allow us to achieve the main goal of micromorphology – the search for specific additional data to improve interpretation of the results obtained in various branches of soil science. For this purpose, it would be most efficient to combine optical microscopy, electron microscopy, micro-chemical analysis and quantitative techniques of image analysis. The micromorphological method of soil analysis has recently been applied in environmental and ecological studies, soil surveys, agronomic research, palaeopedology, archaeology, etc. (Wilding, 1990).

The collection of soil thin sections and associated database in the Dokuchaev Soil Science Institute is an important factor in soil micromorphology development. Soil thin sections have been collected by the Laboratory of Soil Mineralogy and Micromorphology since its organization, i.e., for nearly 90 years. Most of thin sections for Soviet/Russian scientists have been prepared by E.F. Mochalova. There have been recent developments in thin section preparation and microphotography with the use of a new generation of Olympus BX51 polarizing microscopes and Olympus StreamBasic data processing software, which provide possibilities to obtain and analyse high-quality microscopy images using the dynamic scaling technique.

It should be emphasised that improvements of analytical methods imply an interaction between traditional micromorphology and modern tools and techniques, particularly, tomography. There is a

growing demand for macro- and microtomographic soil analyses, which are becoming increasingly more valuable with the development of interdisciplinary studies. Interdisciplinary research projects on infiltration and water-holding capacity of soils in connection with soil pore shapes and distribution patterns, as well as soil structure dynamics in connection with shrink-swell and freeze-thaw phenomena, have been carried out at the Dokuchaev Soil Science Institute using a Bruker SkyScan 1172 scanner since 2012. Internal structures of desert varnish, surface crusts formed after irrigation, calcareous and salt pedofeatures have been examined. A unique tomographic research on primary pedogenesis in hard rocks has been conducted. These studies should lead to the creation of a database of images of the soil structure and pore space, the development of new tomographic criteria of soil degradation and mathematical modelling of soil structure and properties. The combined use of tomography, polarizing microscopy and scanning electron microscopy is a particularly interesting aim of applied research.

Achievements of the modern morphology of soils include the automated analysis of soil colour based on higher spatial resolutions and a wider range of electromagnetic wavelengths beyond visible light. In macromorphological descriptions of soils, it is anticipated that in the near future soil colour will be quantitatively characterized with the use of spectroradiometers.

Publications in the Dokuchaev Soil Science Bulletin include morphological analyses at all scales (macro-, meso-, micro- and submicro-). A system of methods to diagnose soil salinization diagnostics has been presented for the first time; it implies a combined step-by-step morphological and mineralogical (including chemical) analyses of salt pedofeatures at meso-, micro- and submicro- scales. This system includes chemical analyses (water extract composition, gypsum and calcium carbonate contents), micromorphological (polarizing optical microscopy, scanning electron microscopy with X-ray microanalysis and tomography) and mineralogical techniques (immersion analysis, X-ray diffraction and thermal analysis). Salt and gypsum pedofeatures of saline soils formed within a wide range of environments, from extremely arid deserts to forest-steppes, have also been characterized for the first time.

Concepts of pedogenic processes in typical and migrational-mycelial Chernozems have been confirmed by observations of highly

dynamic and diverse calcium carbonate pedofeatures and new data on the activity of qualitatively diverse mesofauna. Postagrogenic features in soils have been carefully examined on different scales.

In the past five decades, our notions about the diagnostic morphological criteria of Vertisols have been developed, and new data on the formation of these soils under a wide range of bioclimatic conditions have been obtained. An important break-through was connected with the application of spatial approaches (transects across the gilgai microrelief), trench method and detailed morphological analysis of not only genetic horizons but also their characteristic morphological elements (morphons).

Research on the structure and composition of soil-like systems in the extreme climates of East Antarctica has revealed a broad range of potential applications of micro- and submicroscopic analyses in diagnostics of modern processes of biochemical weathering under cyanobacterial biofilms, *in situ* synthesis of carbonates and oxalates and migration of ferruginous compounds. Such studies are very valuable for fundamental science, including the search for the origin of life in the Universe.

During the recent decades, the micromorphological method has been broadly recognized as one of most constructive and promising techniques for solving a wide spectrum of geoarchaeological problems that can not be tackled by other methods of soil science and earth sciences in general. There is a prospectively growing application of micromorphological analyses to archaeological objects with the aim of improving interpretation of data from studies on ancient cultural remains.

The prospects for palaeogeographic research are associated with microbiomorph analysis – a combined investigation of microscopic particles of biogenic nature (plant detritus, phytoliths, pollen, etc.). Taking into account that such components are formed under different environmental conditions, their identification within successive layers of pedosediments broadens the horizons of palaeopedological reconstructions. Results from studying Early Pleistocene deposits in Armenia containing stone tools of ancient hominids (Early Acheulian) have allowed palaeoclimatic reconstructions for the period of the ancient hominid migration. Micromorphological data have been applied to interpret the record of pedogenesis in palaeosols formed at the northern

geographical extremity of the MIS3 palaeopedosphere (including the Bryansk fossil soils).

Recently, a new soil information resource has been ratified in Russia – the Unified State Register of Soil Resources of the Russian Federation (2014). It contains unified digital data set on all soils of the country, their properties and spatial distribution. In digital format, this document opens a possibility for restoring morphogenetic characteristics of soils in the form of visually available text without loss or distortion of information. The accuracy of soil descriptions supplied by their authors is being controlled and supported by the completeness of metadata on the given field of soil science, including morphological data.

The above evidence demonstrates the great potential of applying morphological methodology and completely justifies the publication of plenary presentations at the conference in a unified format of the special issue of the Byulleten Pochvennogo instituta im. V.V. Dokuchaev.

For citation: Ivanov A. L. Soil morphology: new challenges and opportunities, *Byulleten Pochvennogo instituta im. V.V. Dokuchaeva*, 2016, Vol. 86, pp. 3-6. doi: 10.19047/0136-1694-2016-86-3-7