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Features of micromorphological structure of forest podzolic soils on loamy and sandy parent material

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As is known, the chemical composition of forest floor has a considerable influence on the processes of soil-formation, especially on general aspect and intensivity of biochemical transformations of organo-mineral matter in soils. Relationships between vegetative cover and soil are studied at present from different points of view by means of many research methods, including the micromorphological analysis of soil profiles. Microscopical investigation of soil thin sections permits to state details of the natural structure of soil constituents and to determine the character of segregation, transformation and interaction of organic and mineral matter. Podzolic soils, perhaps due to their wide range natural differences in constitution, chemical properties and biological characteristics, have been studied in this respect insufficiently, while this problem represents an object of considerable scientific interest.

The present paper deals with the results of a micromorphological study of two distinctly different profiles of podzolic soils, which are most frequent in some north-western regions in the European part of the forest belt in the U.S.S.R. (Leningrad district). These soils were investigated under varying external conditions of vegetative cover and parent material. Thus, the soils investigated are found in two distinct environmental situations and it will be of interest to compare their micromorphological features.

The first profile represents a soddy-podzolic loamy gleyed soil derived from a ribbon clay parent material under bilberry and wood sorrel (Oxalis) spruce-pine forest. Herbaceous plants and green mosses present in the forest floor.

The second profile represents a sandy illuvial humus podzol under bilberry pine forest with sphagnum spots.

The major attention by studying soil thin sections was directed towards the investigation of microforms of mobile substances, because they express most dynamical aspects of soilforming process. Some biogenic formations were also examined.

Soddy-podzolic loamy soil is characterized by a thin (9 cm) humus A_1-horizon overlaid by a fairly well mineralized forest litter. Beneath a poorly differenciated and thin A_1-horizon podzolic horizons A_2 and A_2B are distinguished. Further below a compacted illuvial horizon exhibits a marked horizon differenciation. The illuvial horizon is gradually merging into a loamy parent matter free of boulders. The illuvial horizon is underlaid by ribbon clay at depth of 100-120 cm. The site is affected by a temporal surplus moistening due to surface high water. The soil is rich in ferruginous concretions and is gleyed mostly in the lower part of the profile. The entire profile of sandy podzol is of a typical illuvial-humus appearance. It has a sharply distinguished podzolic upper part and an illuvial Bh-horizon of a dark colour that is due to illuviated humus and iron constituents. A thin layer A_1A_2 consisting of quartz grains and containing rough organic residues is overlaid by peat and moss cover of the forest floor. The soil profile is derived from sandy parent material of lacustrine-glacial origin.

Table. Inorganic matter content of forest litter

Soils	Total ash content %	Percentage of ash						
		SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	CaO	MgO	K_2O
Soddy podzolic loamy soil	3.82	26.50	10.54	6.93	8.13	23.15	6.32	7.63
Illuvial humus sandy podzol	2.34	33.04	14.75	10.70	9.31	14.09	1.96	5.80

The Table represents quantitative data on values for inorganic matter content of litter of both studied soil profiles.

The figures presented in the Table show that litter is rich in biogenic silica in both types of soil, but litter of spruce-pine forest contains considerably greater amounts of organogenic elements as compared to the floor of pine forest growing on sandy podzol. Due to the difference in mineral composition of predominant vegetation the process of transformation of litter plant residues occurs in both investigated phytocoenoses with unequal intensity and leads to unlike results under the conditions of different granulometric composition of both soils.

This difference is reflected by micromorphological features of the investigated soil profiles.

It should be pointed out that the evolution of soddy-podzolic soil takes place under environmental conditions which are more favourable to biochemical transformation of forest litter. Characteristic forms of organic matter determine micromorphological aspects of the soil profiles. Various stages and different degree of decomposition of plant residues may be observed in the litter. Not only fragments of vegetative tissues of cellular structure, but also heavily eroded cells are distinguished. Dark-brown colloidal clots are exposed on the background of cellular tissue, partly destroyed. Great magnification (10×60 and 10×90) discovers multiple hyphae exposures of some fungi and separate colonies of microbial cells. Therefore the general micromorphological pattern of the soil profile is characterized by a rather intensive mineralization and humification of litter.

A high biogenic silica content of litter was favourable to conduct a special examination of microforms related to the segregation of silica from plant residues in the shape of multiple phytolites at various stages of exposure (Fig. 1). In the soddy-podzolic soil phytolites were also observed microscopically in dry sediment of lyzimetric water and in the upper genetic soil horizons A_1 and A_2. They were discovered in the soil in a comparatively little amount (2-3 phytolites on the slide). Some soil

Fig. 1. The appearance of phytoliths in the forest litter. Horizon A_0 of the soddy-podzolic loamy soil. Magnif. 12×60.

phytolites as compared with the litter ones have rather corroded edges that proves the process of its partial dissolution. All these results of the investigations are to be checked and estimated quantitatively be means of study of a greater number of thin sections. This problem is of special interest in connexion with the data furnished by the recent studies by T. V. Aristovskaya on the possibility of dissolution of biogenic silica in microzones of podzolic soils containing alkaline products of microbial vital activity [1].

[1] The unpublished report by T. V. Aristovskaya at the All-Union conference on forest biocoenology, Moscow, December 1968.

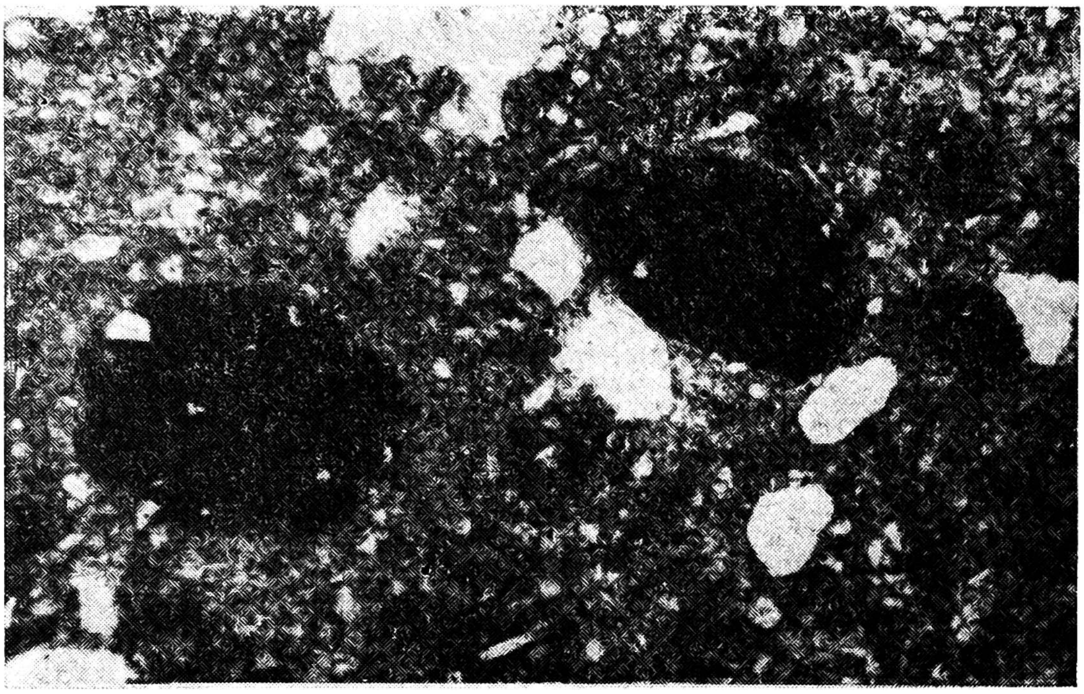

Fig. 2. Humus, loam and compact microortsteins. Horizon A_1 of soddy-podzolic loamy soil. Magnif. 12×3.5.

The A_1-horizon of soddy-podzolic soil is poorly aggregated. Humus consists of loose aglomerations, is partly dispersed (Fig. 2), and in general is not mobile being partly bound with biogenic calcium eluviated from the litter (Table). However, in accordance with the ochre-brown colour of organic matter exposed in reflected light, iron-bearing constituents play a major part in the process of precipitation. Dark humus iron concretions (microortsteins) are fixed in a considerable amount. They have mostly compact structure and a sharp outlook (Fig. 2). Clay particles are distributed uniformly in individual spots being coloured by iron oxides and having a scaly orientation.

It may be agreed that described features of the A_1-horizon indicate a relatively high accumulation of organic-mineral substance and its stability in this horizon, as well as a predominant accumulation of iron. The last appears as the result of weathering of iron-bearing minerals (biotite, augite, magnetite), and as a product of litter mineralization (Table). General accumulative character of soil-forming process within the entire A_1-horizon is verificated by ionic composition of lyzimetric water [5].

Beneath the A_1-horizon the mobilization of ferruginous substance increases with depth and ferruginous new formations acquire very different forms. Within the A_2B-horizon iron concretions are mostly numerous and diversified. They are represented by a plenty of heavily corroded forms, as well as by diffuse units which are surrounded in separate spots by zones of low iron content. At the same time newly formed small ferruginous patches can be distinctly seen. All these formations are characteristic of periodicaly repeated processes of alternate accumulation and dissolution of ferruginous soil constituents. To all appearance the A_2B-

horizon should be considered as the zone of a major active relationship between components of the soil-forming process. On the other hand, a local mobilization of iron and a downward influx of ferruginous water occur during the podzolization, and the influence of a temporal overmoistening of soil accompanied by the dissolution of iron hydrodioxides takes place. Ferruginous new formations are found to be less stable in the lower layers of the soil profile, as the degree of gleyization increases. Diffuse forms of microortsteins, iron enriched rings, and extensive rusty strips represent typical micromorphological features of the soil profile.

The biological nature of ortsteins is now out the doubt [1]. Microscopical examination of ortsteins in soil thin sections at a great magnification supports this concept. Bacterial colonies of cellular-filamentary structure are seen very distinctly on microphotographs in voids and in edge zones of microortsteins (Fig. 3). These structures are masked by an envelope of ferruginous sediment increasing in the course of time. Thus, the major part of the investigated soil profiles is affected by an active bacterial accumulation of iron. Growing microortstein concretions are observed in the soil profile beginning from the top layer to the B_1-horizon. They arise partly in pores through which iron-organic solutions migrate.

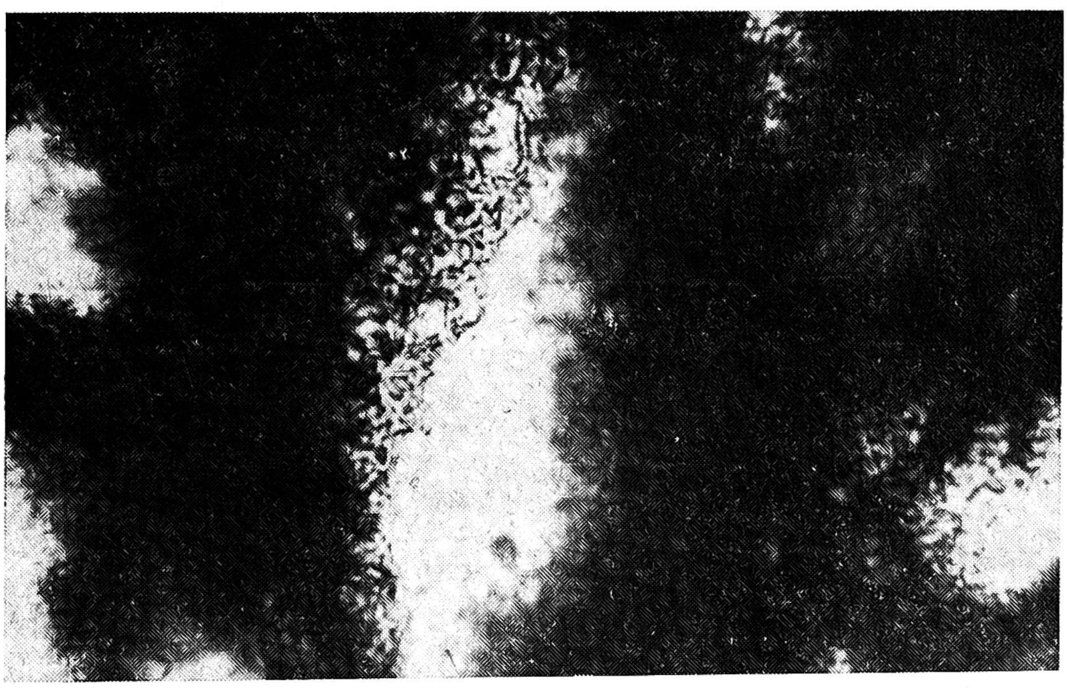

Fig. 3. Colonies of microorganisms covered by iron deposits in the pores of microortstein. Horizon A_1 of soddy-podzolic loamy soil. Magnif. 12×60.

Another distinctive peculiarity of the studied soddypodzolic loamy soil should be noted: the mobility of optically orientated clay that is characteristic in general of many forest soils [2, 3]. A flow of fine dispersed polarizing material translocating through micropores and fissures of soil may be seen within the soil profile from its podzolized part to the illuvial horizon, where orientated clay particles are deposited in cutan and sinter forms. As shows a specific colouration of clay particles in reflected light, precipitation of clay substance occur partly in combination with iron.

Within the B_1-horizon shell-like accumulations of clay appear to have an admixture of organic matter.

Summarized micromorphological features of the investigated soddy-podzolic loamy soil led to the following conclusion:

1. Process of the mineralization and humification of plant residues is noticeably active; the major part of humus is chiefly bound by iron in the A_1-horizon.

2. The shape and the quantity of newly formed ferruginous soil constituents widely change along the entire soil profile. Three zones of the Fe-accumulation may be distinguished: (a) a zone of chiefly bacterial accumulation of iron (A_1-horizon); (b) a zone of increased Fe-mobilization during the podzolization that is characteristic of periodically repeated accumulation and dissolution of iron (A_2- and A_2B-horizons); (c) a layer of intensified migration of iron with increasing gleyization (B_1- and B_2G-horizons).

3. Podzolic horizons are poor in silt and humus content, while cutans and sinter-accumulations of polarizated clay partly connected with iron oxides are abundant within the illuvial horizon.

The second object of our investigations was a *sandy illuvial humus podzol*. It derives under environmental conditions characterized by a slow decomposition of forest litter. Lyzimetric study reveals a very poor infiltration of mineralized solutions through peaty litter.

The micromorphological examination confirms that fragments of vegetative matter with pretty well preserved pattern of cellular skeleton and debris of conducting vessels of plant tissues constitute the major part of litter layer. The minor part of vegetative tissues is poorly polarizing. Humified patches present in a considerably less amount as compared with litter of soddy-podzolic loamy soil. However, round-shaped and compacted small lumps of organic matter (caprolites produced by components of soil microfauna) are marked out in a noticeable quantity. Distinct phytolites are seen within mineralized tissues, while within the mineral soil horizons they are solitary. It appears that coarse-pore texture of sandy matter is not favourable for precipitation process.

The A_1A_2-horizon located immediately beneath the litter cover is characterized by features of organic accumulation. Mineral soil substance consisting chiefly of quartz grains contains fairly numerous plant remnants in the shape of angular carbonizated particles. Accumulations of rough organic matter not connected with mineral grains are marked out on the external surfaces of mineral grains and between them (Fig. 4). Organic matter, examined in reflected light, has an ochre colouration due to the presence of iron. At great magnification it reveals a high saturation with microflora.

Fig. 4. Accumulation of rough organic matter on the background of mineral grains. Horizon A_1A_2 of the sandy podzol.

Podzolic A_2- and A_2B-horizons are of whitish colour because of a great amount of washed quartz sand particles. Practically these horizons contain neither humus nor ferruginous sediments. A little accumulation of organic matter may be seen only on thin sections of rootlets. Vegetative tissues are of different degree of decomposition. At a greater magnification round-shape accumulations of humificated organic substance are distinguished by spots. On their edges fine opal formations, probably of biogenic origin, are present.

Debris of feldspar (microcline, plagioclase), hornblende, mica, etc. are distributed between quartz grains. The surfaces of all these mineral aggregates are covered mostly by a brown coating, and appear to be corroded.

The immediate microscopical examination of the A_2-horizon has shown that the coatings are formed by abundant bacterial colonies. A great magnification (12×40 and 12×60) permits to see some details of the colonies and of mineral grain surfaces corroded by micro-organisms. The same phenomena are observed within the A_2B-horizon. Fairly coarse debris of weathered biotite are found here. A magnified picture of one of these debris shows that the foliated structure of the mineral is destructed, and developing voids of erosion are filled by round-shape concretions of iron hydroxide with vague bacterial cells. Two clear strips of sediment of a low refractions index are marked out along the central axe. Probably, it is an opal formation (Fig. 5).

Thus, phenomena of the biochemical weathering of minerals are distinctly fixed on thin section of podzolic soil. It appears that this process in the case of the investigated mineral substance could be rather intense, but its absolute effectiveness is not very important. Moreover, it is not accompanied by marked accumulation of secondary weathering mineral products.

A brownish-yellow and a darker colloidal matter may be seen within the illuvial B-horizon on the surfaces of mineral aggregates and in inter-granular spaces. This colloidal substance is composed by sediment of organic mineral complexes of iron and apparently of aluminium which migrate downwards from upper soil horizons. The colloidal accumulations become more compact in separated micro-spots. On the contrary, in other parts of the soil profile, a finest light-yellow cutan partly teared off is present. The colloidal matter is isotrope and does not contain optically

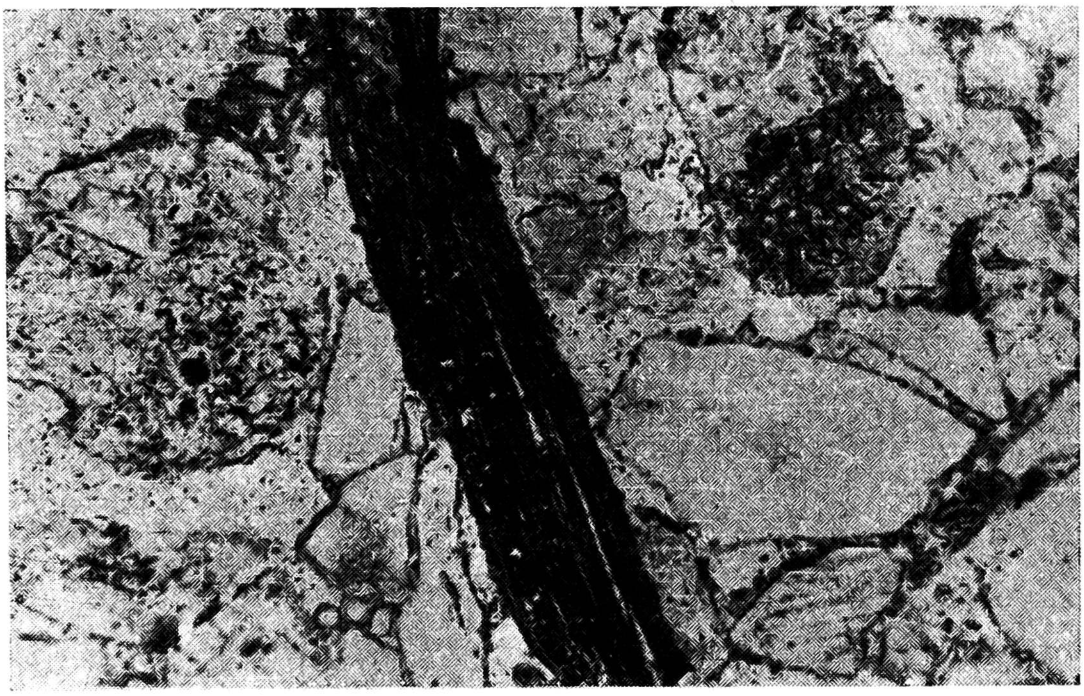

Fig. 5. Brown microbial pellicle on the surface of minerals and the fragment of biotite changed by weathering. Horizon A_2B of the sandy podzol. Magnif. 12×9.

polarizated clay. At a great magnification it is shown that the major part of surfaces of organic-mineral aggregates is covered by microflora. The last appears to play a role in processes of further biochemical transformation of humus and iron within the illuvial horizon of sandy soils [1]. The character of the development of microbial colonies corresponds to the round forms and the general structure of organic-mineral colloidal accumulations (Fig. 6).

Changes in mineral grains and surficial bacterial coatings occur within the illuvial horizon less intensively than in the podzolic one, where the major part of grains is protected by organic-mineral cutans. One might speak also of selective property of the microflora in relation to different minerals and various soil matter. Our investigations show that most dense bacterial colonies inhabite the surface of plagioclase (Ca-Na) and of mica. Quartz grains are poorly covered by colonies.

Signs of illuviation of organic-mineral complexes and of biochemical processes of weathering are weakly expressed in the B_2-horizon. Colloidal

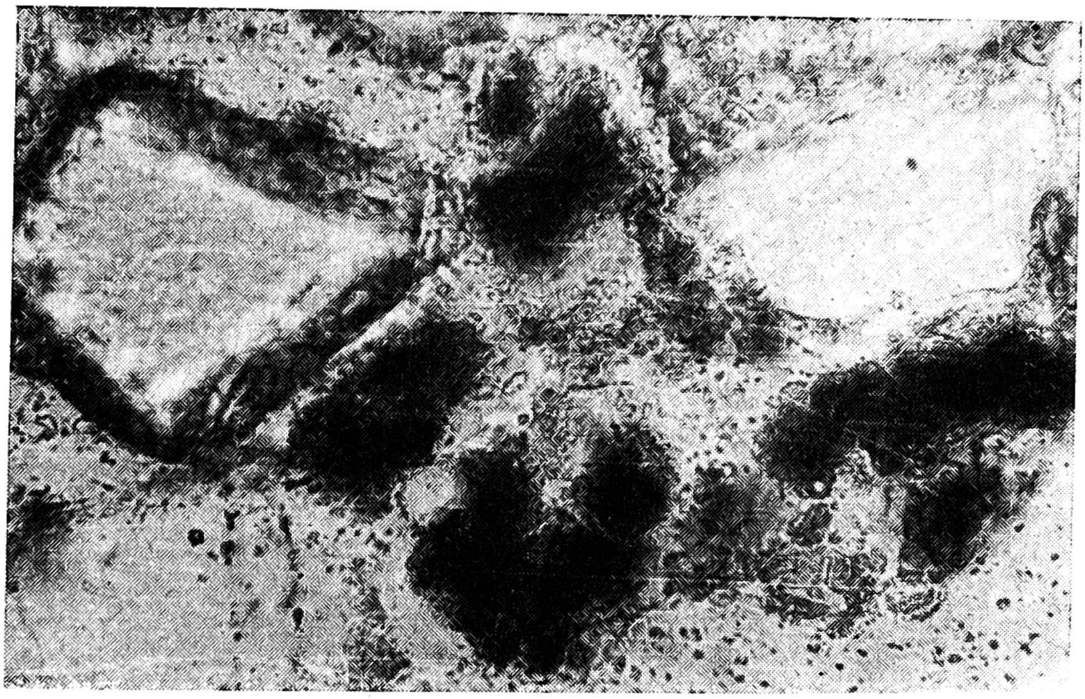

Fig. 6. Organo-mineral colloidal sediments enriched by microflora. Horizon B of sandy podzol. Magnif. 12×20.

formations are presented here by fine pieces of teared off cutans which are scantly inhabited by microflora or are even free of it. Solitary grains of feldspar are partly corroded.

The following points may be noted as the result of studies on micromorphological features of sandy podzol:

(1) processes of humification are weakly developed within the mineral part of the soil profile, while the content of the rough organic matter in the upper thin A_1A_2-horizon is relatively high;

(2) signs of biochemical weathering of minerals are expressed chiefly in the podzolic horizons; the intensity of this process is not high, and no noticeable accumulation of clay products takes place;

(3) the illuvial process is expressed by the accumulation of colloidal aggregates of organic-mineral compounds of iron and aluminium. On their surfaces an abundant microflora is discovered. Probably, it plays a significant part in further biochemical transformations of humus and iron within the illuvial horizon of sandy soils.

The investigations carried out show that local features of the pedogenetic processes under definite geographical environment influence on the microstructure of podzolic soils.

On the basis of the investigated relationships between microforms of some soil constituents and biological processes an additional assumption may be made that all these factors play an essential part in the soil evolution.

SUMMARY

The paper deals with micromorphological characteristics of forest podzolic soils on loamy and sandy parent material under different vegetative cover. Local features of the podzolization process distinctly influence on the forms and amounts of the accumulation of mobile soil constituents — iron, clay and organic matter. Relationships between microforms of some soil constituents (humus, ferruginous organic-mineral compounds, biogenic silica), and biological factors of soil-forming process are discussed. A supplementary role of these factors is noticed.

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