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Andrzej MANECKI *

AEROMINERALOGY — MINERALOGY OF ATMOSPHERIC DUSTS

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A b s t r a c t. This paper deals with mineral composition and origin of atmospheric dusts and their classification. In the present author's opinion, the branch of mineralogy devoted to the problems of natural and artificial dusts should be called aeromineralogy.

INTRODUCTION

Atmospheric dusts are generally examined using chemical methods. However, much more informations can be obtained by means of mineralogical studies. These data can be summarized as follows:

1) phase composition of dusts,

2) proportion of natural and artificial dusts,

3) grain-size distribution and morphology of grains and their aggregates,

4) contents of water-soluble, heavy and magnetic fractions,

5) chemical composition of both bulk material and of individual grains,

6) changes of mineral composition of dusts taking place in the atmosphere due to photochemical reactions.

Taking into account the mineral composition of dusts it is possible to determine physical properties of individual constituents (e.g. their solubility in water), their chemical composition and eventual toxical features. Consequently, it is possible to estimate the influence of dusts (especially of artificial ones) on geochemical character of natural environment. Recently, much attention is paid to the study of the degree of contamination of atmosphere. It is proposed to call aeromineralogy this branch of our

* Academy of Mining and Metallurgy, Institute of Geology and Mineral Deposits, Cracow (Kraków), al. Mickiewicza 30.

science which is dealing with the study of both natural and artificial dusts, similarly as cosmomineralogy is devoted to extraterrestrial matter.

Rapid development of industry and transport, concentrating within densely populated regions, results in considerable increase of the amount and activity of centres producing impurities suspended in atmospheric air. Geological (e.g. volcanic) and cosmical processes, as well as penetration of men into the cosmic space, influence considerably the chemical composition of atmosphere by introducing various dusts and gases. The finest dust particles are migrating passively in the atmosphere up to the hight of several thousands meters and at large distances. In its lower parts, where water vapour is present, they form heterogeneous systems — hydrosols and aerosols, in which photochemical reactions between dust and gaseous particles take place. Consequently, dusts of both natural and artificial origin can change their composition, whereby primary and newly formed substances can jointly exert noxious influence, exceeding their individual separate actions. Moreover, some types of organisms are also suspended in atmosphere. This aeroplancton consists e.g. of diatomea, small insects, pollens, unicellular algae, spiders and spores of Bryophytae.

METHODS OF INVESTIGATIONS OF DUSTS

Atmospheric dusts are multi-phase systems and, thus, have to be often preliminarily prepared for examination, usually by means of separation procedure (Manecki 1974). In the first stage, the material under study is subdivided in distilled water into soluble and insoluble fractions, the latter being afterwards separated using sedimentation method. Soluble fractions is recovered by thorough evaporation, whereby during the final stage the temperature should not exceed 40°C. Insoluble fraction, after drying, is subdivided in bromoform into light and heavy mineral assemblages and followed by separation of magnetic grains by means of permanent magnet. If the sample under examination is small, only the first stage separation is applied.

Phase composition of separated dust fractions is usually determined by means of microscope observations in polarized light, X-ray study and infrared absorption spectroscopy. Optical properties of water-soluble fractions are estimated after crystallization from a drop of solution placed on mounting slide. For microscope examination of insoluble fractions of dusts, powder preparations are used obtained by sedimentation on mounting slide and fixed with Canada balsam. Infrared absorption spectroscopy is used for determination of soluble components of dusts whilst in examining the insoluble fraction — to estimate the nature of organic compounds. Valuable data are obtained by determining the size, shape and morphology of grains and their aggregates by means of scanning microscopy. Special additional equipment enables simultaneous estimation of chemical composition of the material studied. In these examinations very useful are McCrone's & Draftz's text books (1974).

Chemical composition of individual grains is determined by means of electron microprobe analysis. Separated fractions of dusts can be examined using atomic absorption spectroscopy and non-distructive radioisotope X-ray fluorescence (Florkowski, Piórek 1974). Estimation of even sub-trace

amounts of uranium as well as its distribution and concentration in individual dust grains can be carried out by means of fission track method (Manecki, Skowroński 1976).

CLASSIFICATION OF DUSTS

Atmospheric dusts are generally classified according to their grain-size. These, consisting of grains 5—1 μm in size, are considered to be the most noxious for human organism. Generally, all the contaminating atmospheric dusts are subdivided into two (natural and artificial) or four groups:

1) products of erosional action of wind,
2) industrial,
3) combustion products,
4) others.

The classification of inorganic fraction of atmospheric dusts is presented in tables 1 and 2, being a modification and evolution of systematics

Table 1

General classification of inorganic fraction of dusts occurring in terrestrial atmosphere

Dust type	Variety
Natural	Cosmic Terrestrial Impactitic
Artificial	Industrial Radioactive Originated in circum--terrestrial zones
Mixed	Products of photochemical reactions in atmosphere Products of other physico-chemical changes in atmosphere

Table 2

Classification of inorganic fraction of natural dusts

Variety	Type
Cosmic	Micrometeorites Products of ablation of meteorites Of asteroidal origin
Terrestrial	Eolian Volcanic Originated from sea water Products of great fires of vegetation Of biological origin
Impactitic	Impactites

proposed earlier by the present author (Manecki 1975). Three main types of dusts are distinguished:

1) natural, formed during natural processes taking place on the Earth surface or in cosmic space,
2) artificial — caused by human activity on the Earth and within circum-terrestrial zone,
3) mixed — formed in atmosphere as the product of superposition of natural processes and human activity.

NATURAL DUSTS

Cosmic dusts. Total mass of annual fall of matter of extraterrestrial origin is evaluated to approx. 1 mln. tons. Meteoritic matter corresponds to negligible part of this amount. The majority of this matter is represented by small spherulic particles called cosmic dusts. It was found that this matter consists of camacite, taenite, magnetite, native nickel and glass (Wieser 1963, Cadle 1966, Manecki, Skowroński 1970). It is computed that since Cambrian the mass of our planet increased by approx. 1—2.5 $\times$ 10^{15} tons i.e. by 0.1 per cent.

Terrestrial dusts. In this group eolian and volcanic dusts were distinguished, as well as those generated from sea water, during great fires of vegetation and of biological origin. Eolian dusts are products of combined action of weathering factors and of eolian erosion of rocks and soils. They consist of a characteristic mineral assemblage composed essentially of quartz and subordinate feldspars, carbonates, micas, clay and heavy minerals. From time to time violent winds are outblowing from desert areas, beaches and glacier marginal zones considerable amounts of dusts. Falls of eolian dusts were reported to occur in different parts of Europe and in 1973 and 1974 were noted in the Tatra Mts. (Manecki *et al.*, in print).

Volcanic dusts are represented by the finest fraction of pyroclasts and consist essentially of glass particles with subordinate grains of feldspars (particularly their high-temperature modifications), micas, pyroxenes, amphiboles and iron oxides. After eruption of Katmai volcano in Alasca in 1912, the produced dust covered large continental area up to the distance of several hundreds kilometers from the centre with a layer 3—120 cm thick.

Fogs coming from oceans and seas introduce into atmospheric air crystals of chlorides (consisting in 70% of NaCl), the total mass of which is evaluated to be 2 $\times$ 10^{9} tons per year. They are widespread up to 300 km inside continental areas. During great fires of vegetation (woods, steppes) the ashes produced contain numerous grains and fragments of superficially fused silicate minerals and of glass. These dusts resemble artificial ones generated during combustion of solid fuels.

Dusts of biological origin consist essentially of organic components produced by plants. Palynologic analysis of eolian dusts supported by meteorological data determining conditions of their falls allows to indicate their source areas. Such investigations were carried out for eolian dusts falls in the Tatra Mts. (Manecki *et al.*, in print). Inorganic components of dusts of biological origin are represented usually by diatomea.

Impactite dusts, being very common on lunar surface, are reported to occur sporadically close to terrestrial meteoritic craters. They usually consist of marginally fused fragments of glass and of silicate minerals, being products of abrupt collisions of larger meteorites with Earth's surface.

ARTIFICIAL DUSTS

These dusts are by-products of human activity on the Earth's surface and within circum-terrestrial zones. Because of their participation in dustiness of atmosphere, these dusts are examined from the viewpoint of protection of natural environment. Their total presence in terrestrial atmosphere is documented e.g. by measurements carried out in Peruvian Andes (Manecki, Schejbal, in print) i.e. in highland terrains very distant from any larger industrial agglomerations. Phase composition and morphological features of numerous varieties of artificial dusts differ from those of natural ones. The former are usually products of mechanical disintegration processes (e.g. grinding, abrasion — dispersion dusts) or result from solidification of vapour particles — condensation dusts. Radioactive dusts generated during nuclear explosions are very dangerous too. Finally, some contamination of the highest zones of terrestrial atmosphere is caused by rapid development of satellite technique. It is proposed to distinguish three varieties of artificial dusts: 1. industrial, 2. radioactive, and 3. dusty products of rocket engines, braking within circum-terrestrial zones.

Actually, industrial dusts dominate in contamination of atmosphere. Usually, they are by-products of the following processes:

— combustion of solid and liquid fuels,
— production of metallurgical industry,
— cement production,
— production of fertilizers,
— production of ceramic industry,
— production of abrasives,
— productions of detergents and cleaning chemicals,
— production of catalysts.

Combustion products are easy to identify by means of optical and scanning microscopy. They consist of spheroidal particles of glass, magnetite, grains of quartz and its high-temperature modifications and mullite. During metallurgic processes dusts of condensation type are usually formed whilst cement, fertilizer and ceramic industries produce dispersive dusts (originating essentially due to grinding of mineral raw materials) and artificial phases (e.g. compounds of clinker).

MIXED DUSTS

Natural and artificial dusts and gases emitted into atmosphere are subjected to alteration resulting in the formation of new chemical compounds. During these processes particular role is attributed to gases and aerosols (Junge 1963). Mixed dusts can be the products of photochemical reactions proceeding in atmosphere or of another physico-chemical changes. So e.g. sulphur dioxide is photochemically oxidized in the atmosphere, whereby iron and aluminum oxides acts as catalysts. In the presence of water vapour sulphuric acid is formed which, in turn, combines with Ca, Mg, Pb and other metal compounds to form various hydrated sulphates. As follows from mineralogical examinations of atmospheric dusts deposited in Cracow and Ojców National Park (Manecki 1975, Manecki, Michalik 1975), calcium sulphate is the main component of their water-soluble fraction. In these processes considerable role is played by nitrogen oxides. In the areas of larger town and industrial agglomerations, these changes can significantly influence regional aerosanitary conditions causing distinct alteration of geochemistry of natural environment (Bolewski *et al.* 1976).

FINAL REMARKS

Dusty and gaseous contamination connected with rapid development of industry and transport rapidly increases, contributing to the general dustiness of atmospheric air by natural dusts. The resultant action considerably influences the geochemistry of natural environment. Mineral and chemical composition of atmospheric dusts, their origin and secondary transformations are very interesting and important problems of aeromineralogy.

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Andrzej MANECKI

AEROMINERALOGIA — MINERALOGIA PYŁÓW ATMOSFERYCZNYCH

Streszczenie

W pracy przedstawiono klasyfikację pyłów atmosferycznych. Scharakteryzowano ogólnie skład mineralny i genezę wyróżnionych odmian. Zaproponowaną klasyfikację materii nieorganicznej pyłów atmosferycznych przedstawiono w tabelach 1 i 2. Wyróżniono trzy główne odmiany pyłów:

— naturalne, utworzone w naturalnych procesach zachodzących na Ziemi lub w Kosmosie,

— sztuczne, wywołane działalnością człowieka na Ziemi lub w strefie okołoziemskiej,

— mieszane, utworzone w atmosferze w wyniku nałożenia się procesów naturalnych i działalności człowieka.

W ostatnich latach poważnego znaczenia nabierają badania stanu zanieczyszczenia atmosfery ziemskiej. Stwierdza się wyraźny wpływ zwłaszcza pyłów przemysłowych na zmiany geochemii naturalnego środowiska. Dział mineralogii, zajmujący się pyłami atmosferycznymi, proponuje się nazwać aeromineralogią.

Анджей МАНЕЦКИ

АЭРОМИНЕРАЛОГИЯ — МИНЕРАЛОГИЯ АТМОСФЕРНЫХ ПЫЛЕЙ

Резюме

В работе представлена классификация атмосферных пылей. В общем характеризуется минеральный состав и генезис выделенных разновидностей. Предложенную классификацию неорганического вещества атмосферных пылей, представляет таблица 1 и 2. Выделено три главные разновидности пылей:

— природные, образованные в естественных процессах происходящих на Земле или в Космосе,

— искусственные, вызванные деятельностью человека на Земле или в околоземной сфере,

— смешанные, образованные в атмосфере в итоге наложения естественных процессов и деятельности человека.

В последние годы важное значение имеют исследования состояния загрязненности земной атмосферы. Обнаруживается явное влияние, особенно промышленной пыли, на изменения геохимии естественной среды. Раздел минералогии, рассматривающий атмосверные пыли, предлагается назвать *аэроминералогией.*