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PYROCLASTIC ROCKS IN DEPOSITS OF THE POTASSIC SUBFORMATION OF THE PRIPYAT INTRACONTINENTAL PALAEORIFT

Natalia S. PETROVA

Republican Unitary Enterprise "Belarusian Research Geological Exploration Institute"; Kuprevich str. 7, 220141 Minsk, Belarus; e-mail: belnigri@list.ru

Abstract: The paper presents characteristics of composition, structure and distribution pattern of tuffaceous interbeds of the Mid-Late-Famennian potassic subformation of the Pripyat intracontinental palaeorift (the Pripyat Trough, Belarus). Solid products of volcanic activity found there are proofs of significant volcanism influence/contribution on/to accumulation of salt deposits in the Pripyat Trough. Abundance of clastic material, its granulometric and mineralogical composition and distribution within the sedimentary area affected formation of lithological complexes. Interbeds of tuffaceous clays, occurring at 12 levels of the potassic subformation, suggest that the salt accumulation was accompanied with the volcanic processes. Pyroclastic rocks are represented by ash particles (morphologically well-preserved in some crystal-vitric tuffs), pumice, mineral crystals and lithoclasts.

Key words: tuffite, potassic subformation, Pripyat palaeorift

The Pripyat potassium-bearing basin, located within the Pripyat palaeorift (Aizberg *et al*. 2001) was formed as a result of the Earth's crust response to the processes that had occurred in the deeper lithosphere horizons (Fig. 1). A peculiar feature of the intracontinental palaeorift is the continental-type crust occurring in the basin bottom. The formation of the Mid-Late-Fammenian potassic subformation within the Pripyat Trough coincided with the stage of the rift graben maturity, which was characterized by various manifestations of magmatism, firstly, by volcanic processes.

The sedimentary infilling of the potassic subformation is a rhythmic alternation of salt and non-salt rocks. Pyroclastic rocks are most often represented by recyclites, immature products formed due to decomposition of igneous and metamorphic rocks. The volcanism acts as a supplier of juvenile materials.

A regular recurrence of volcanic eruptions is responsible for many internal peculiarities of the sedimentary infilling structure. Several geologists believe that just the presence of the volcanic rocks in the continental rifts differs their formation series from those of the collision basins.

Many researchers have mentioned a particular abundance of pyroclastic rocks in deposits of the potassic subformation. In the opinion of Korzun & Makhnach (1977), the volcanic activity was of undersea and island character.

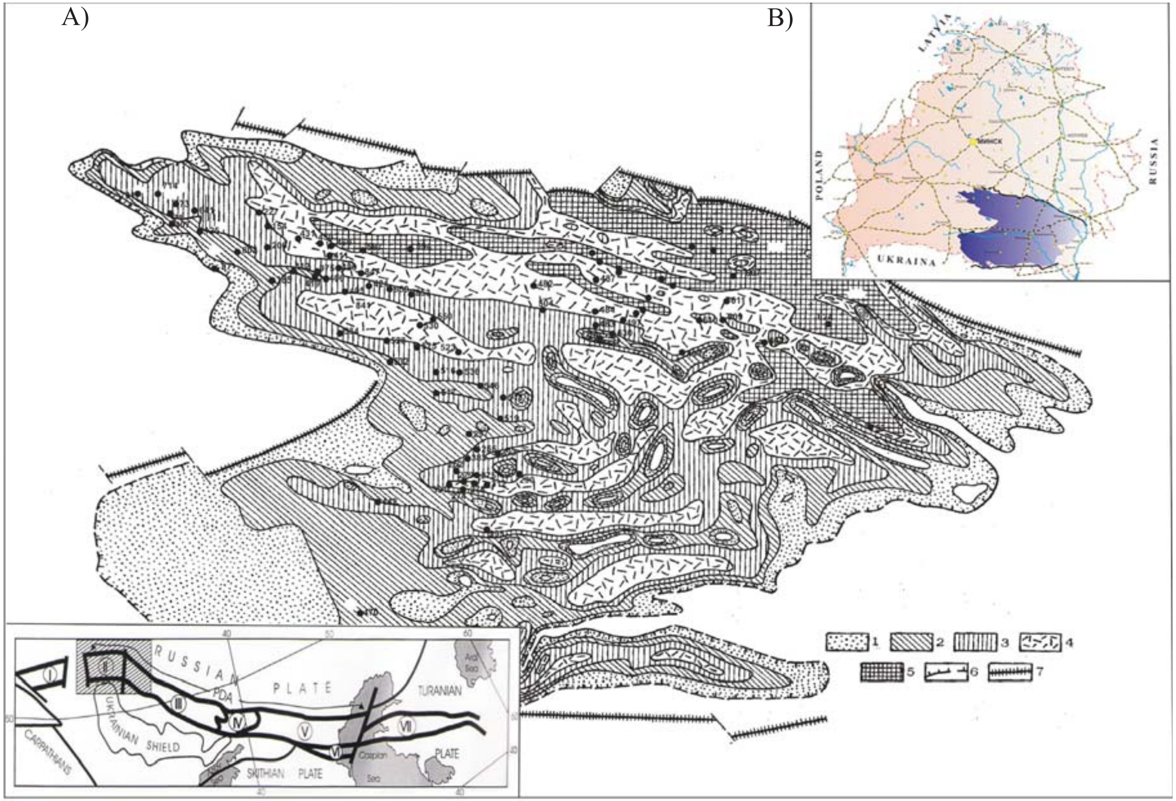

Fig. 1. Location of the study area: A) Position of boreholes within the Pripyat Trough from which tuff beds were studied. Fields of bassets of rhythmic bundles of the potassium-bearing subformation: 1 – I–II; 2 – III–IV; 3 – V–VI; 4 – VII–VIII; 5 – IX–X; 6 – margins of the rock-salt occurrence within the potassium-bearing subformation; 7 – marginal faults. Solid circles show positions of boreholes. B) Position of the Pripyat Trough on the map of Belarus. C) Position of the Pripyat Trough in the Sarmath-Turanian lineaments. Troughs: I – Podlasic-Brest; II – Pripyat; III – Dnieper-Donets; IV – Donbass fold belt; V – Carpinsky Ridge; grabens: VI – Manych; VII – Mangyshlak; PDA – Pripyat-Donets Aulacogen; the study area is hatched (Aizberg *et al*. 2001)

The synchroneity of the volcanism activity and salt deposition is evidently shown by interlayers of tuffaceous clays traced in the potassic subformation at twelve well-defined stratigraphic levels (Petrova & Shablovskaya 1986a), both inside the salt members, and as inclusions in the rock salt (Fig. 2).

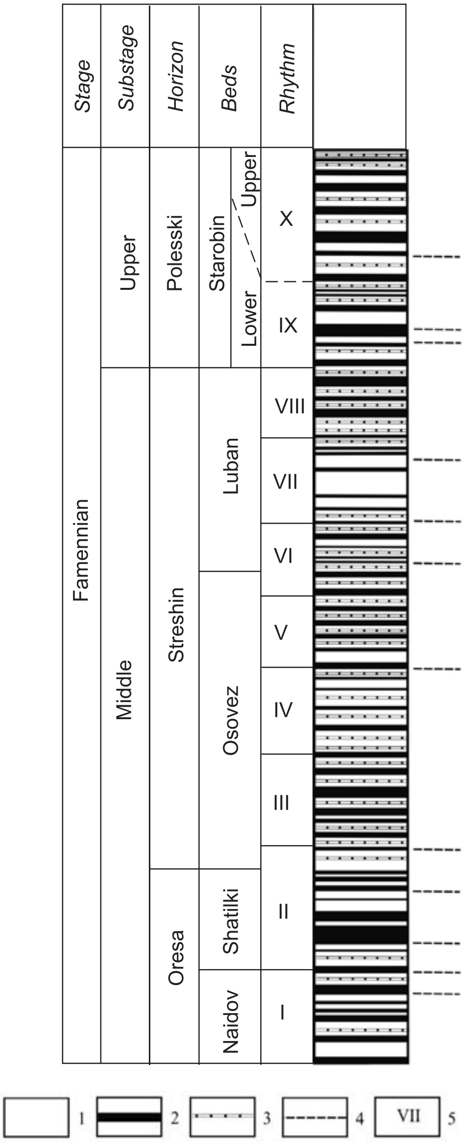

Fig. 2. Schematic lithologic-stratigraphic profile of the potassium-bearing subformation with the tuff bands indicated: 1 – rock salt, 2 – halopelity, 3 – horizons of potash sals, 4 – level of tuffaceous interlayers, 5 – rhytmite number

The aerial extent of each level within the trough is restricted to a rhythmite member, which it is confined to. The thickness of simultaneous formations in the north of the trough increases in the eastward direction. An admixture of volcanic glass was determined in chemical-terrigenous rocks all over the section of the potassic subformation.

Some types of non-salt rocks without distinct relict evidences, observed in the section of the potassic subformation, could be of volcanogenic-sedimentary origin (camouflaged pyroclastics). These are noncarbonate clays showing a peculiar microtexture with the fluidal, felty arrangement of the clay particles with vortices and fan-shaped edges, looking 'silky' in the polarized light, a peculiar type of siltstone (found in the northeast of the Pripyat Trough) with biotite looking like intergrown packs (crystal size up to 0.5–1 cm), sometimes chloritized. These siltstones resemble crystal tuffs (biotite micaliths).

The main body of volcanogenic interlayers is represented by volcanic-sedimentary rocks (derived from the volcanic products but deposited like normal sediments): salt (halite), calcareous, clay tuffites and tuffs (consolidated deposits of volcanic ash) from the contact zone with normal sedimentary rocks.

The rock salt is predominating in pure volcanogenic interlayers, sometimes comprising more than 50% of sedimentary constituents. Anhydrite and calcium and magnesium carbonates occur in small amounts (Petrova & Shablovskaya 1990).

The proper pyroclastic formations and tephrogenic rock associations are distinguished by their accumulation pattern. Tuffuceous interlayers are characterized by a predominance of ash particles (pelitic fractions make up to 80–90%) with a subordinate quantity of lithoclastic and vitroclastic materials.

A reliable diagnostics of pyroclastic material is based on a combination of methods including the field description, optical investigations, observation in the scanning electron microscope, X-ray analysis, the microcomponent analyses, as well as the macrocomponent chemical composition. The studied samples were subjected to fractionation without any vigorous agitation to learn the granulometric composition of the tuff bands. The samples were soaked with water and then washed of soluble salts till a negative reaction for chlorine was reached. Later they were subjected to a slight abrasion in a mortar by a rubber pestle.

In the potassic subformation the pyroclastic material is represented by fine vitric components (mainly ash particles, morphologically well-preserved), pumice, crystalloclasts and lithoclasts. Vitreous and hypocrystalline materials occur in fragments. Vitreous ash, mostly abundant there, was formed as a result of the molten lava disintegration under the effect of the expanding gas, which foamed the magma coming close to the surface. Large bodies of solidified foamy lava form the pumice, but the major part of foam is broken by the gas released, and only small partitions of volcanic glass remain intact.

Vitreous particles occurring in the interlayers are different in shape and porosity: 1) those released in the plastic state are elongated, rod-shaped, more seldom thin drop-like, rounded, with peculiar bended and forked surfaces that formerly were walls of gas bubbles, with Y-shaped fragments that served as partitions between adjoining bubbles; 2) gas-saturated ones, released in the semi-solid state with gas bubbles that look like broken honeycomb and were formed when the magma was saturated with the gas phase and the melt viscosity increased sharply; 3) pumice; 4) pisolites – more or less spherical rock bodies of poorly cemented ash (accretionary lapilli) (Fig. 3). The latter could be formed due to the accretion of ash particles around liquid cores, e.g. rain drops.

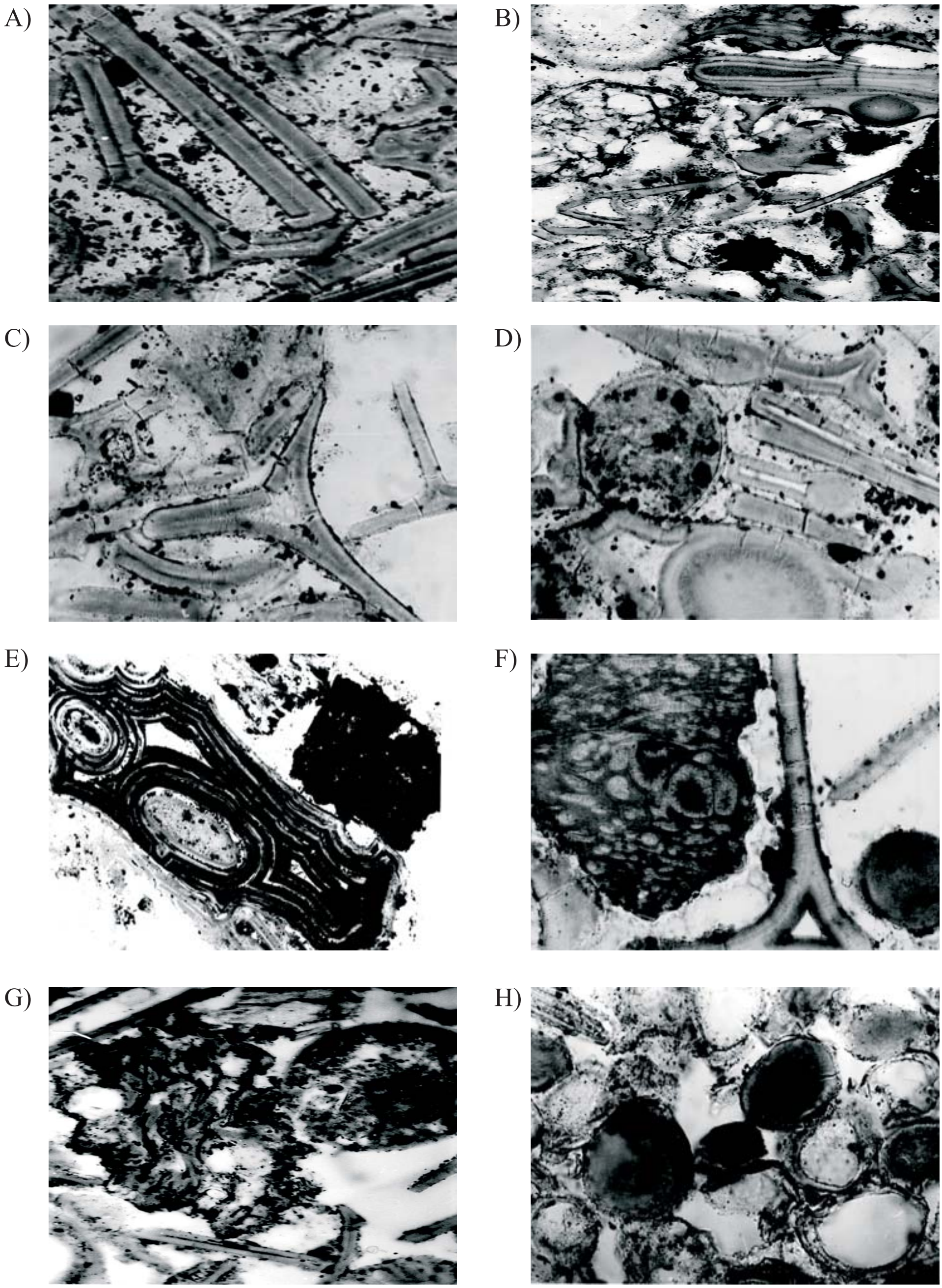

Fig. 3. Morphological features and varieties of volcanic material fragments. Sections: A) 546-49b, ×200; B) 536-198, ×200; C), D) 572-67-4, ×120; E), F) fragment of a fine-blebby pumice, section 165-1 ×200; G) fragment of a lithic pumice, section 562-23, ×120; H) pisolites in a tuffaceous interlayer, section 528-1δ, ×120

Glass fragments vary from greenish-brown to dark-brown in colour. The major part of glass fragments includes some amount of microlites represented mainly by plagioclases, more rarely pyroxene(?). The green glass, showing some evidences of decrystallization, is mostly saturated with microlites and more plastic (more often, intermediate-acidic-N < 1.54, more rarely, basic N > 1.565 in composition).

The plagioclase is the main crystalline constituent of ashes (N 24 to 60). It occurs in two generations: as isolated crystalloclasts and microlites. Crystalloclasts are idiomorphic thick tabular crystals with glass inclusions, often severely altered. The undulating extinction observed in the plagioclase is probably due to the material fragmentation during the explosion.

A dark greenish interlayer with macroscopically visible cross and choppy bedding occurs at the contact with normal sedimentary formations of the sulfate-carbonate composition with rare volcanic material inclusions. The cause of such a bedding is clearly visible by the microscopic study. These are intercalated lamellae of various density. In the denser sites, fork, crescent and spindle-shaped glass fragments are plunged in the slightly greenish, sometimes with yellowish-red hue, devitrified finely divided volcanic glass. In some cases, the glass is a dusted poorly polarized felsitic aggregate, in the other cases, it looks like a chlorite-clayey rock mass flowing around ash particles visible at crossed polars.

Some evidences of the glass carbonization, silicification, ferruginization, devitrification (decomposition) are observed at the contact with the rock salt in a porous body of the tuffaceous interlayers. The phenomena of the flow layer tuff alteration are associated with the transformation of a hot vitric material in the water environment (low-temperature hydrothermal alteration). The fragments are transformed to different extent. In some sites, they are perfectly fresh, in the other they are imperceptibly plunged in the glass decomposition products. In the last case, the transitions are either gradual, or the glass fragments are replaced by the carbonate material, both inside and along the edges.

The carbonate rock is often formed from the tuff at the contacts with normal sedimentary carbonate-clayey rocks. Vitric fragments found in the tuff are chloritized and severely altered. Among vitric clasts there are many ferruginous fragmentary materials, that are most likely broken iron crusts.

The former crystalloclasts found among vitric rock masses are leached and filled with the carbonate material along the edges. The cement developed in several stages.

The ash mineral composition is dependent not only on the magma composition, but also on the transportation and accumulation conditions. The chemical composition of the ash is usually similar to the general composition of the effusive products, as this is essentially the same crushed silicate melt. However, as ashes are subjected to the eolian differentiation and come to a hostile medium of the salt basin, their composition changes. An association of clay minerals studied in the ash tuffs is represented by the hydromica of the polytype modification 1M (of leucophyllite type) and mixed-layered chlorite-smectite and micaceous-smectite nearly ordered formations, while in normal clayey-carbonate rocks of the potassic subformation the clay constituent is described by the domination of the hydromica of the polytype modification 1 Md hydrated to different extent, where the peak 10 gradually slopes toward low angles (Petrova *et al*. 1983). The corrensite is often found in the bottom parts of tuffaceous interlayers. The study of the chemistry of pyroclastic rocks has shown that these may be related to rock varieties both slightly oversaturated, and undersaturated with silica, rich in potassium, depleted in calcium and showing a high colour index (Petrova *et al*. 1983).

The composition of the aluminosilicate (Tab. 1) constituent of reference samples of tuffaceous clays does not entirely correspond to volcanic formations in the northeast of the Pripyat Trough and the northwest of the Dnieper-Donets depression (Korzun & Makhnach 1977). Differences in amounts of some rock-forming constituents are, probably, due to some processes as follow: mixing of various type clastics, eolian differentiation (determined by a distance from the source) and redeposition of the ash material, sedimentary and diagenetic transformations of the volcanic glass and crystalloclasts.

The chemical features are most comprehensively described in terms of the standard composition, which suggests that the hot particle transformation occurred with the silica release and leucophillite formation, and, in the case of tephroides, formation of the chlorite-montmorillonite constituent. In the northeastern regions close to the Bragin-Loev Saddle (Pervomaisk area), chlorite and biotite crystals, up to 5–7 mm in size, in the volcanogenic material increase in abundance. Other minerals occur in small amounts. The lighter material was determined in the studied samples. Heavy minerals are few in number (1–1.2%). The mineralogical composition of the heavy fraction is distinguished by the predominance of iron minerals (ilmenite, magnetite, iron hydroxides, hematite, pyrite) and zircon, some bitumen inclusions are noted.

Peculiar features determined in the composition, structure and distribution pattern of tuffaceous interlayers suggest that the northeastern source of the volcanogenic material supply can be considered as the main one.

At the same time, the comprehensive study of the western sections of the Inner Graben suggests a possible additional source of pyroclastics, which could be sublatitudinal and submeridional deep-seated faults.

The studied tuffaceous interlayers usually show low cobalt, nickel and chromium contents (often below the quantitative spectral analysis response), increased amounts of zircon, niobium, boron, more rarely, strontium. The iron and manganese are noted to be separated during the volcanic material transportation and transformation (Petrova & Shablovskaya 1986b). The distribution of incompatible elements is explained by the nature of transforming melts. The cobalt absence is likely due to the absence of olivine, and the absence of chromium and nickel – to the absence of clinopyroxenes; according to Corliss (1971), just these minerals are responsible for an increase in amounts of the above elements. The distribution pattern of the trace elements depends on the forms of their occurrence in source-rocks of the corresponding volcanogenic material and on the sedimentation environment. The range of contents of the trace elements is largely due to the general rock composition, amounts of chemogenic rocks, and the character of relations between some mineral constituents (Tab. 2).

The boron content of tuffaceous clays is considerably above its clarke value of sedimentary rocks, but is well compared with the increased amounts of this element in intermediate volcanogenic complexes of the Pripyat Trough. The titanium amount is somewhat decreased as compared to its clarke value in sedimentary and volcanogenic rocks.

Table 1

Average standard composition of the aluminosilicate constituent of tuffaceous clay in the potassic subformation of the Pripyat paleorift

Sampling site, mineralogical composition	Oxide content [%]								
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	K_2O	Na_2O	Loss by calcinations at 1000°C
Nezhin area, borehole 411, sample 563, hydromica	54.59	10.82	6.47	0.11	15.71	0.03	5.76	0.34	6.29
Nezhin area, borehole 413, sample 902, hydromica	60.23	13.07	6.93	0.13	7.08	0.01	7.57	0.35	4.83
Nezhin area, borehole 416, sample 735, hydromica	55.19	12.42	6.72	0.93	10.77	0.41	7.76	0.24	5.56
Nezhin area, borehole 416, sample 735, hydromica	56.64	12.31	6.58	0.12	10.69	1.15	7.21	0.26	5.13
Nezhin area, borehole 406, sample 1322, hydromica	59.60	10.94	4.62	0.01	10.68	0.97	7.61	0.61	4.95
Kopatkevichi area, borehole 546, sample 43, hydromica	52.88	13.91	5.05	0.11	8.58	0.08	7.94	0.57	10.86
Kopatkevichi area, borehole 546, sample 48, hydromica	54.38	13.76	6.82	0.01	7.16	0.01	7.75	0.75	9.40
Kopatkevichi area, borehole 528, sample 80/1, chlorite-montmorillonite	33.21	15.07	19.55	0.31	18.73	0.02	2.36	0.80	10.02
Kopatkevichi area, borehole 528, sample 80/36, chlorite-montmorillonite	33.12	7.32	24.49	0.24	20.64	0.01	2.76	1.11	10.32
Kopatkevichi area, borehole 528, sample 80/5, hydromica+chlorite-montmorillonite	47.54	15.56	6.72	0.42	9.79	2.07	7.67	0.35	9.86
Smolov area, borehole 582, sample 89/1, hydromica	50.32	8.11	9.75	0.61	14.14	1.33	7.46	0.68	7.61

Table 2

Trace element distribution in tuffaceous clay rocks of the potassic subformation of the Pripyat paleorift [ppm]

Name	Number of samples	Trace element content [ppm]									
		Cr	Ni	Co	V	Mn	Ba	Ti	Zr	Nb	B
Tuffaceous clay rocks (bulk samples)	44	<1–23* 4.5	<1–40 3	<1–28 2	<1–95 16	32–450 92	20–55 30	120–3000 1267	100–900 415	15–220 144	120–600 361
Fraction < 0.001 mm	22	<1–50 7	<1–12 3	<1–6 1	<1–84 15	25–160 73	10–35 20	520–2500 1197	100–720 405	130–200 163	350–560 463

* variation ranges in the numerator, average value in the denominator

The zircon content in tuffaceous clays is 2–3 times and even higher than its clarke value in sedimentary rocks. The Zr/Ti ratio turned to be an indicator value used to recognize the volcanogenic nature of sedimentary rocks of the potassic subformation. The Zr/Ti values in tuffaceous clays coincide with this ratio values in volcanogenic rocks of the Pripyat Trough. The nickel, cobalt and chromium contents of the studied tuffaceous clays are usually below the spectral response of the quantitative analysis. The general trends of the trace element distribution determined for tuffaceous clays coincide to some extent with those revealed for rocks of volcanogic formations in the northeast of the Pripyat Trough (Korzun & Makhnach 1977), however, it is quite possible that more acidic ash falls of volcanic eruptions that took place in the territory of the Dnieper-Donets Depression contributed greatly to the pyroclastic material supply during the potassic subformation accumulation.

The genetic diagram of Zr-Ti hydrolyzates (Fig. 4) can be used to distinguish tuffaceous formations in the potassic subformation, which is especially important to identify camouflaged pyroclastics in the section of intervals.

During the study of the behaviour of incompatible elements three groups of rock associations were distinguished:

1) niobium – zircon – boron, showing the increased clarkes of concentration;
2) titanium – barium – manganese – vanadium with the decreased clarke values;
3) chromium – nickel – cobalt with the decreased clarkes of concentration.

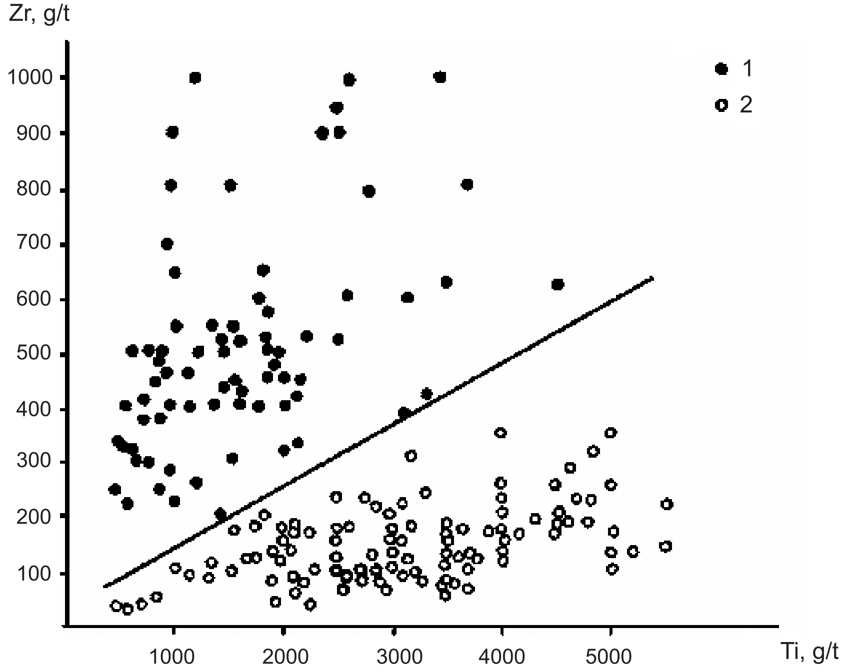

Fig. 4. Genetic diagram of Zr content against Ti content. Conventional symbols: 1 – tuffaceous formations, 2 – chemical-terrigenous rocks of potassium-bearing and potassium-free zones of the potassic subformation

Pyroclastic products from eruptions of central-type volcanoes were spread to many tens of kilometers, formed interlayers of volcanic tuffs mainly of compound basaltic--trachytic composition. The shape of ash fragments clearly defines their origin. The ash and lapilli layers are usually well sorted by the fragment size, both in the vertical and horizontal directions. The sorting index depends on the eolian differentiation and explosion intensity.

An increased interest shown to the volcanogenic materials in sedimentary formations was due to their possible use for several purposes: correlation of deposits (ash layers are of great importance for geologists because can serve as time references); characterization of the accompanying magmatism; prediction of several attendant mineral deposits.

The halogenesis phenomenon has recently attracted the particular attention of geologists, as its contribution to the formation of the composition of the Earth's sedimentary cover and hydrosphere comes to be better understood. Mineral occurrences associated with halogenic formations are widely used by mining industry, which poses numerous theoretical and applied problems to be solved by investigators. One of the important and complicated problems to be solved is the importance of volcanic processes for the generation of chloride salt strata in the sedimentary fill of paleorifts. The real contribution of the volcanogenic material to the accumulation of clastics in the potassic subformation of the Pripyat Trough and its influence upon the evolution and fundamental mechanisms of salt accumulation are still underestimated. Fine pyroclastics supplied could promote the moisture absorption and stronger concentration of solutions, equalizing the solid and liquid phase volumes.

Synthesis of the data available on the Late-Devonian magmatism of the Pripyat Trough and the adjacent areas permits a conclusion that volcanogenic formations widespread there are typical of continental rifting zones. Evidences of rifting magmatism of the Pripyat area are as follow: occurrence of high-alkaline rocks, including the ultrabasic alkali ones; diversity of the magmatism manifestation involving an explosion character of volcanic eruptions and abundant intrusions into the platform cover at various levels of the consolidated crust; migration of the volcanic activity from the peripheral to axial parts of the paleorift.

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