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LEAD ISOTOPES IN GALENAS OF THE WEST CARPATHIANS

(Figs. 4, Tabs. 6)

Abstract: In the paper the authors evaluate isotopic analyses of 45 galena samples from various deposits and finding-places of the West Carpathian region. Isotopic analyses of lead have been carried out with precision 0.15 % (2 σ limit). The data interpretation and model age calculations are based on Stacey — Kramers' (1975) model. Interpretation of results is not simple as far as a complex structure of the West Carpathians is concerned; the mountains undervent two orogenic processes (Variscan and Alpine) at least. Neogene metallogeny of subvolcanic character is also very expressive here. Granite plutonism appeared as a possible source of plutonogenic metallogeny in both the orogenies (Variscan and Alpine).

Interpretation of model ages on the basis of Pb-isotopes in galenas from the Tatro-Veporide region implies, in majority of cases, relation to Variscan metallogenetic processes; in the Gemerides, on the other hand, to the processes of hydrothermal metallogeny of Alpine age (Neoidic). Besides this, some syngenetic ore mineralizations in the Gelnica Group in the Spišsko-gemerské rudohorie Mts. (Smolník region) bear lead proving the Lower Palaeozoic model age (400—600 Ma.) on the basis of isotopic analysis.

In spite of the fact that isotopic composition of galenas from the Neogene deposits shows only very slight differences, it provides valuable materials for solving mutual genetic relations of various types of ore mineralizations in the area of the Central Slovakian neovolcanites.

Some anomalies of isotopic composition give a lowered model age and they have to be explained by the presence of radiogenic lead (so-called "J" anomaly, which appears in the region of the Malé Karpaty Mts., in Tatro-Veporides and in some localities of the Spišsko-gemerské rudohorie Mts.). Another type of anomaly — the so-called "B" anomaly occurs in Tatro-Veporides but in Gemerides too, in this case the model age of lead is higher than the age of ore mineralization, cf. Nižná Slaná in the Spišsko-gemerské rudohorie Mts. and deposit Trangoška in the Nízke Tatry Mts.

Резюме: Авторы в статье оценивают изотопные анализы 45 образцов галенитов из разных местонахождений и местонахождений района Западных Карпат. Изотопные анализы свинца были сделаны с точностью 0,15 % (2 б лимит). Интерпретация данных и вычисления модельного возраста

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основаны на модели Стейси — Кремерса (1975). Интерпретация результатов не проста что касается сложново строения Западных Карпат, которые претерпели минимально два орогенных процесса (варисцийский и альпийский). Очень ярка здесь и неогенная металлогения субвулканического характера. Гранитный плутонизм проявился как возможный источник плутоногенной металлогении в обоих орогенезисах (варисцийском и альпийском).

Интерпретация модельных возрастов на основе изотопов свинца в галенитах в районе татровепоридов показывает, в большинстве случаев, связь с варисцийскими металлогенетическими процессами в гемеридах, с другой стороны, с процессами гидротермальной металлогении альпийского возраста (неоидные). Кроме того, некоторые сингенетические оруденения в гелницкой серии в Спишско-гемерском рудогорье (окрестность с. Смолник) содержат свинец подтверждающий на основе изотопов нижнепалеозойский модельный возраст (400--600 млн. лет).

Несмотря на то, что изотопный состав галенитов из месторождений неогенного возраста показывает лишь очень малые разницы, он предоставил ценные материалы для решения взаимных генетических отношений разных типов оруденений в районе среднесловацких неовулканитов.

Некоторые аномалии изотопного состава дают пониженный модельный возраст и их необходимо объяснить наличием радиогенного свинца (т. н. „Дж“ аномалия, которая проявляется в районе Малых Карпат в татровепоридах и на некоторых местах Спишско-гемерского рудогорья. Следующий тип аномалии, т. н. „Б“ аномалия встречается в татровепоридах, но и в гемеридах, когда модельный возраст свинца выше чем возраст оруденения, напр. с. Нижна Слана в Спишско-гемерском рудогорье, месторождение Трангошка в Низких Татрах.

Introduction

The isotopic composition of lead is one of the most important characteristics of lead from which conclusions on the genesis of ore deposits can be drawn. The interpretation of isotopic composition of lead, however, is not always unequivocal, but many cases are known from the literature when problems of the source of lead in ores, association of mineralization with magmatism and some other problems of ore geology, petrology and metallogeny could have been resolved on this basis. Of a number of important papers we refer at least to the studies of Černyšev — Pavlov, 1980; Delevaux — Doe, 1972; Köppel — Schroll, 1979; Sato — Sasaki, 1973.

Thanks to new experimental techniques is mass-spectrometry, in 1970', the precision of data on the Pb isotopic composition greatly increased, making 0.1—0.15 % by contrast with 0.5 % attained in 1960'. Such a refinement of data was needed with respect to the fact that the differences in the values of Pb isotopic ratios — ^{206}Pb/^{204}Pb, ^{207}Pb/^{204}Pb and ^{208}Pb/^{204}Pb vary within a range of several tenths of one per cent to several per cents in very extensive ore districts, ore fields and even in single deposits. Only this higher precision of analytical data permitted to proceed from the study of general problems to the solution of more detailed problems concerning individual deposits or ore districts. On this more perfect basis new interpretation models were developed some years ago, which describe the evolution of the isotopic composition of terrestrial lead in more detail and precision (Stacey — Kramers, 1975; Doe — Zartman, 1979).

The circumstances mentioned above also influenced the approach of the authors to the study of the isotopic composition of ore lead in the West Carpathians in Slovakia. On a relatively small territory ore mineralizations occur there in different metallogenetic epochs, especially in the Variscan and Alpine tectono-magmatic cycles. Syngenetic ore mineralizations in the Spišsko-gemerské rudohorie Mts. sometimes with galena and sphalerite contents (areas of Smolník, Mníšek, etc.) were formed during the Cambro-Silurian sedimentation and their development was completed by metamorphic and geological events that affected the crystalline Gemerides (Gelnica Group). Subvolcanic deposits associated with Neogene volcanism show a particular character. Ore deposits and occurrences in limestones and other carbonates of both Palaeozoic and Mesozoic age are of questionable age and their sources of Pb are likewise uncertain.

Geological, tectonic and geochemical conditions of the location of Pb-Zn mineralization, composition of wall rocks and mineral parageneses with galena are very different. Therefore, it was interesting to study the variation of isotopic composition of lead within relatively small areas. Correlation of the isotopic characteristic of lead with the genetic type of mineralization also enabled the isotopic data to be used for recognition of the origin and source of metals on the West Carpathian ore deposits.

In the course of investigations carried out on the basis of bipartite cooperation plan of the institutes of the Soviet (IGEM) and Czechoslovak Academies (Geological Institute of the Slovak Academy of Sciences (SAV)) a number of new mineralizations and indications discovered in the last 10—15 years have been examined in the Slovakian part of the West Carpathians and some isotopic studies have been conducted on the known deposits. The Czechoslovak workers of the Geological Institute SAV (Cambel) and of the Faculty of Sciences, Komenský University in Bratislava (Koděra) provided samples of various mineralization types from the Slovak West Carpathians. The Soviet collaborators (IGEM AN U.S.S.R, Moscow — Černyšev) applied their experience gained in the study of Pb isotopes in ores by means of methods that give results of a high precision corresponding to the present world standard.

In the first stage of investigation, whose results are recorded in this paper, only the isotopic composition of lead in galenas has been studied. Analyses were made of 45 samples from ca. 20 deposits and ore occurrences, including those studied before by Kantor and Rybár (1962, 1964). (For location of these deposits see Fig. 1.). Considering the method available in 1960,' the authors managed to establish many characteristic features and trends of the development of Pb isotopes in galenas of the West Carpathians, in spite of a lowered possibility of accurate determination of isotope contents. Their study is to be regarded as an extraordinarily important and pioneer work for the West Carpathian regions. Kantor—Rybár (1964) used for their conclusions the model ages determined by isochron method of Holmes—Houtermans.

A brief description of regions with galena occurrences

In the West Carpathians mineralization with galena occurs in three geological regions of particular metallogenic characters: in the crystalline complex of the Tatro-Veporides, in the Spišsko-gemerské rudohorie Mts., and in the areas of Neogene volcanics. Accordingly, we have divided the galena samples into three basic groups (1—3). Several indications in Palaeozoic and Mesozoic limestones and dolomites exploited in the past have been classed in a special group 4.

1. Galena-bearing mineralization in the Tatro-Veporides

In the Core mountains and Veporides (Tatro-Veporides) hydrothermal Pb-Zn deposits and occurrences of vein type are known from both crystalline schists (migmatite, gneiss, phyllite) and granitoids. The only relatively large deposit is situated near the village Jasenie in the Nízke Tatry Mts., where ore veins with galena occur mainly in gneiss and migmatite. The remaining mineralizations in the Nízke Tatry Mts. (where it is often associated with Sb-mineralization), other Core mountains (Malé Karpaty Mts., Malá Magura and Suchý Mts.) and the Veporides are only meaningless ore indications.

A characteristic feature of the West Carpathians is the predominance of Variscan granitoid plutonism and progressive metamorphism of sedimentary rocks, associated with it. This opinion is based on a number of geological and geochronological data.* In the opinion of some authors, the crystalline complexes of the West Carpathians are made up to a major extent of rocks originated during several Precambrian orogenic cycles. Such hypotheses have recently been published by J. Kamenický — L. Kamenický (1983). However, not even this most recent publication has brought convincing evidence (geological, palaeontological or geochronological) for the existence of Lower, Middle and Upper Proterozoic cycles, although the presence of such rock complexes cannot be ruled out.

Hydrothermal plutonic vein mineralization in the Tatro-Veporides displays diverse genetic marks. The age, whether Variscan or Alpine, of some occurrences is the subject of discussion. A direct association of the Variscan or Alpine age of mineralization with the age of granite plutonism is presumed, i. e. of the intrusions of various acid granitoid differentiates. The era of Variscan magmatism might have lasted from the Middle or Late Devonian until the end of the Permian (porphyry magmatism), with hydrothermal aftermaths in the Early Triassic. This can be demonstrated with the deposit at Trangoška (Nízke Tatry Mts.), where a barite vein occurs at the boundary between the Lower Triassic and underlying migmatites, penetrating partly into the Lower Triassic quartzite. The model age of galena from this mineralization is 320 Ma, as yielded by both our and Kantor — Rybár's measurements (1964). An alternative explanation is that we are concerned here with ore deposits of Variscan age that were displaced in post-Triassic time. This theory is supported by the fact that some mineralizations occur in the Alpine mylonite zones, viz. in the dislocation zones of granitoids.

Another disputable and still unresolved problem is the origin of ore components in hydrothermal solutions. A more or less direct source of these substances may be Variscan or Alpine granitoid plutonism and energy at depth, which activated the fluids and water as a constituent part of the rock. The passage of hydrothermal solutions through the sedimentary series obviously will cause changes in the isotopic composition of lead. It will be influenced by the environment, the lithology of metamorphosed rocks and by isotopes of lead which is dispersed in rocks or occurs in synsedimentary ore accumulations.

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* Kantor, 1959; Cambel et al., 1982; Cambel — Vilinovičová, 1981; Dunej — Siegl, 1984.

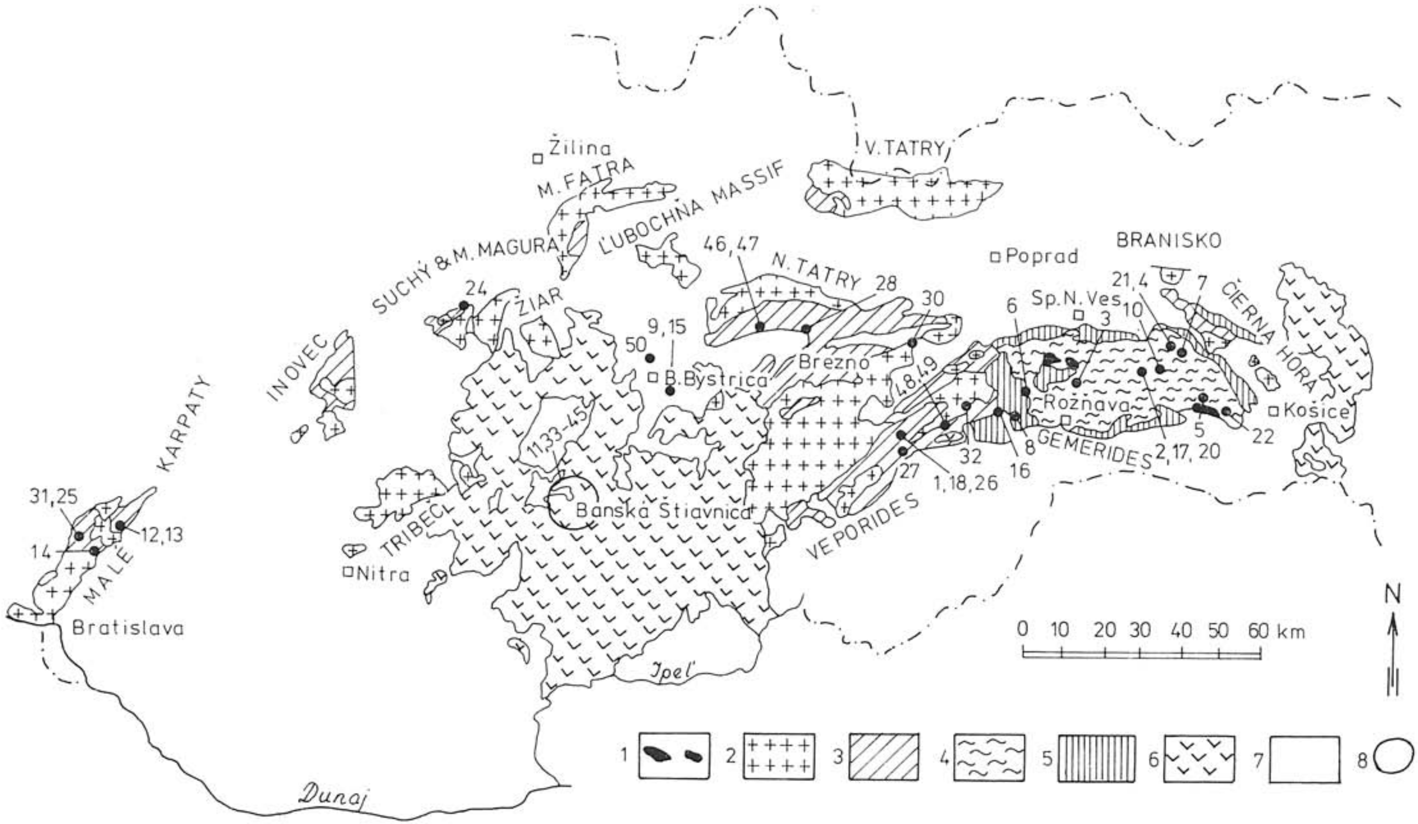

Fig. 1. Geological map of Czechoslovak part of the West Carpathians with position of the studied deposits and ore indications Numbers in the scheme correspond to numbers of samples in the tables, graphs and in the text.

Explanations: 1 — granitoids of the Spišsko-gemerské rudohorie Mts. (Late Variscan (?), Cretaceous (?)); 2 — Variscan granitoids; 3 — crystalline schists from the Tatro-Veporides (phyllites, gneisses, migmatites); 4 — crystalline rocks in Gemerides (phyllites, porphyroids, diaphtorized metabasites, amphibolites and gneisses and also their primary, undiaphtorized types); 5 — Upper Palaeozoic — Carboniferous and Permian (mainly verrucano facies) rocks in Gemerides; 6 — region of occurrence of Neogene volcantites and tuffs; 7 — post-Permian formations (Mesozoic, Tertiary and Quarternary); 8 — limitation of the region of sampling from deposits in Banská Štiavnica area.

2. Galena-bearing mineralization in the Spišsko-gemerské rudohorie Mts.

The Spišsko-gemerské rudohorie Mts. is built up of Palaeozoic and Mesozoic complexes of the Gemeride tectonic unit. The Gelnica Group of Cambro-Silurian age appears to be the oldest unit. The Rakovec Group is younger, probably Devonian. Both of them were metamorphosed several times, mostly to greenschist facies and locally up to the amphibolite facies, and often diaphthorized. Carboniferous, Permian and Triassic sediments represent younger systems. Small bodies of Gemeride granites are late Variscan and Alpine (Jurassic--Cretaceous) in age.

Hydrothermal mineralization comprises mainly veins of siderite-sulphidic and antimonite formations, metasomatic deposits of siderite and magnesite and the Sn-W formation. Additionally, there are numerous sedimentary-exhalative and sedimentary deposits and occurrences of different age as, for example, pyrite and polymetallic ores in the Gelnica Group, uranium mineralization in the Permian or hematite mineralization in Permian evaporites. Owing to this, the chronological interpretation based on the Pb isotopes ratio is difficult, as although the lead is present in small amounts in most of the mineralizations mentioned above, its genetic association with them is not always demonstrable.

The samples of galena from the Spišsko-gemerské rudohorie area have been divided into two subgroups: 2.1 with galena from the vein deposits of the siderite-sulphidic formation, and 2.2 with galenas from synsedimentary deposits of the Gelnica Group. Galena occurrences in carbonate rocks constitute a separate group 4.

The opinions on the age of hydrothermal mineralization, presumably directly or indirectly associated with the Gemeride granites, differed (Variscan, Alpine, endogenous or tectono-metamorphosed, regenerated). After the radiometric age of the Gemeride granite had been determined by Kantor (1957, 1959, 1960), the mineralization was dated as Alpine by most authors. According to recent age measurements, however, part of the Gemeride granites is thought to be late Variscan and part Alpine, Jurassic-Cretaceous (Kantor — Rybár, 1979; Kovách et al., 1979), which has complicated, naturally, the dating of hydrothermal mineralization. Some authors admit Variscan mineralization for at least a part of deposits, even if ore mineralization partly occurs in Permian and exceptionally Triassic complexes or developed after Alpine tectonic processes and overthrusts. In may be accepted that the formation of such younger ore accumulations is due to Alpine rejuvenation and displacement of Variscan or earlier primary mineralization, or to the remobilization of elements from the most varied Palaeozoic rocks of the Gemerides and disseminated ores in them. Mineralization of this Palaeozoic syngenetic type occurs e. g. in the areas of Smolník, Mníšek and Bystrý Potok. These views of remobilization have already been expressed by Ilavský (1962, 1979). Nowadays, it is believed that the mineralization in the Spišsko-gemerské rudohorie Mts. was most probably associated with endogenous processes connected with younger Neoidic (Alpine) magmatism. It has not yet been clarified how great was the importance of the Alpine tectonometamorphic hydrothermal remobilization of elements for metallogenesis.

3. Mineralization with galena in neovolcanics of Central Slovakia

The third area with occurrences of polymetallic and other mineralization types with galena is the region of Central Slovakian neovolcanics. The most important, at present exploited, are the deposits of polymetallic (Pb-Zn-Cu-Ag) ores in the Štiavnica — Hodruša ore district (Böhmer — Štohl, 1968; Koděra, 1960, 1963, 1969). The Zlatá Baňa polymetallic ores in the Slanské vrchy Mts. in eastern Slovakia are recently second in importance. Galena from the Tisovec deposit (sample 32), genetically associated with neovolcanics is also placed in this group.

The mineralization types of the Štiavnica — Hodruša ore district can be divided into two subgroups, arranged chronologically from the oldest to the youngest (with great probability):

3.1. Mineralization genetically associated with the Hodruša intrusive complex (lower Badenian), including three types:

— magnetite skarns in Triassic limestones and dolomites, genetically associated with the Hodruša granodiorite, with predominant magnetite ores and superimposed impregnated polymetallic mineralization (galena, sphalerite, chalcopyrite, pyrite); Vyhne-Klokoč deposit (sample 43);

— porphyry-copper mineralization with predominant chalcopyrite and pyrite and a small amount of galena and sphalerite located chiefly in skarns. This type of ores is connected genetically with dykes of granodiorite porphyry (Burian — Smolka, 1982); Zlatno deposit near Banská Hodruša (samples 44, 45);

— polymetallic impregnated-stockwork, and metasomatic mineralization developed mainly in granodiorite. It very likely predates the dacite dykes and has been discovered by mining works in the Rozália Mine between the Rozália and Bakaly veins (samples 40, 41 — vein type, samples 37, 42 — metasomatic type).

3.2. Post-dacite (upper Badenian?) subvolcanic vein and metasomatic ores with two types:

— polymetallic (Pb-Zn-Cu-Ag) Štiavnica type accompanied with metasomatic mineralization, developed on the Banská Štiavnica deposit and in the eastern part of the Banská Hodruša deposit (Rozália and Bakaly veins). Mineralization developed in six phases, the non-metallic (quartz) periods having alternate with polymetallic ones (samples 11, 33—36). Metasomatic ores (sample 38) were associated with the 4th period;

— silver-bearing quartz-carbonate veins of the Hodruša type with a low polymetallic mineralization — represented by veins in the central and western parts of the Banská Hodruša deposit. Mineralization is also of pulsation character; an alternation of nine, quartz and carbonate, periods has been recognized (sample 39).

The opinions on the age and genetic associations of the individual types in the wider area of the Štiavnica—Hodruša ore district differ. The main subject of discussion is the age of the Hodruša intrusive complex (regarded either as equivalent to Cretaceous banatites or as a depth equivalent of neovolcanics) and of skarn mineralization associated with it. Problematic are also interrelationships between individual types and their ages: Fe-skarns, porphyry-copper ores of Zlatno type vs. impregnated stockwork mineralization in granodiorite; impregnated stockwork mineralization vs. polymetallic vein and metasomatic Štiavnica types; and the Štiavnica vs. Hodruša mineralization types. The results obtained by isotopic study of galena lead have contributed to the solution of these problems.

4. Mineralization with galena in carbonate rocks

Galenas from numerous small occurrences and minor accumulations occurring most frequently in Triassic (Ardovo, Poniky — sample 15. Pohorelská Maša — sample 30 and others) and Carboniferous carbonate rocks, (Ochtiná — sample 8) or in magnesite bodies (Burda deposit — samples 1, 18, 26) have been placed in the separate group 4. The authors do not agree about the genesis and age of this polymetallic mineralization. It was considered to be epigenetic, syngenetic, regenerated, and was dated as Triassic up to Neogene. However, the isotopic composition of Pb from these occurrences is very similar and suggests their association with Neogene volcanism.

The results obtained and method of isotopic analysis

The results of isotopic analyses of 45 galena samples are listed in Tables 1—4. Analyses were made in the Institute of geology, petrography, mineralogy and geochemistry of ore deposits, Academy of Sciences USSR in Moscow. The analytical method is given below. The samples were provided by the authors, and part of them was abtained through the kindness of co-workers of the Faculty of Sciences, Charles University, D. Štúr Geological Survey, museums and other institutions. The model ages derived from isotopic ratios are presented in Fig. 2. Where possible, our results were compared with those of Kantor — Rybár (1964) and of Kantor (1962); the isochron graph of Holmes — Houtermans (Fig. 4) is added because these authors used it for interpretation of some galena samples from the West Carpathians (Holmes, 1946, 1947; Houtermans, 1947, 1953).

Measurements were made using a Soviet mass spectrometer MI-1320 (Černyšev et al., 1983 a) and the technique of silicate-gel activator for ionization of lead. The methods used in mass spectrometry and for chemical preparation of samples have been described in detail by Černyšev et al., 1983 b. The values of ^{206}Pb/^{200}Pb, ^{207}Pb/^{204}Pb and ^{208}Pb/^{204}Pb ratios are given in Tables 1—4; they have been standardized according to the standard sample of the USA National Bureau of standards SRM—981 (Catanzaro et al., 1966). The total effect of mass discrimination for applied instrument and analytical method, corrected after SRM—981 standard was 0.08 % per mass unit. The resulting maximal error in the results does not exceed 0.15 % which, expressed in units of isotopic ratios, is about 0.022 for ^{206}Pb/^{204}Pb and ^{207}Pb/^{204}Pb, and 0.060 for the ^{208}Pb/^{204}Pb ratios.

The two-stage model of Stacey — Kramers (1975) for the evolution of isotopic composition of lead has been accepted, which brings well into accordance the most authoritative constants and parameters of isotopes. Let us inspect the evolution diagrams of ^{206}Pb/^{204}Pb — ^{207}Pb/^{204}Pb and ^{206}Pb/^{204}Pb — ^{208}Pb/^{204}Pb ratios, in which the results are plotted (Fig. 2).

Table 1

Group 1. Deposits and ore accumulations in Tatroveporide crystalline complex

Sample No.		Locality	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
25	MK	Below Baba, lower adit	18.706	15.687	38.728
31	MK	Below Baba, upper adit	18.713	15.695	38.769
12	MK	Častá, lower adit, dumps	18.505	15.673	38.559
13	MK	Častá, lower adit	18.587	15.673	38.611
14	MK	Pezinok, Sb-deposit, bore hole KV-29	18.384	15.646	38.452
24	SMM	Čavoj, Gápeľ, Mandel adit	18.471	15.674	38.562
28	NT	Trangoška	18.368	15.664	38.582
46	NT	Deposit Jasenie, Soviansko hill	18.342	15.642	38.502
47	NT	Deposit Jasenie, Soviansko hill	18.348	15.641	38.542
50	NT	Cu-deposit, Špania Dolina	18.626	15.686	38.620
27	VEP	Ostrá hill near Hnúšťa	18.525	15.636	38.692
16	VEP	Rochovce, Dubina valley	18.562	15.627	38.586

Explanatory notes: MK — Malé Karpaty Mts; SMM — Suchý and Malá Magura Mts.; NT — Nízke Tatry Mts.; VEP — Veporides.

Localization of samples: No. 25 — below Baba hill, dumps of lower adit. Quartz veins with pyrite, sphalerite, galena, arsenopyrite and Sb-sulphosalts in the Lower Palaeozoic gneisses; No 31 — below Baba hill, dumps of upper adit. Analogous to sample No 25, barite present in veinstone too; No. 12 — village Častá, dumps of lower adit, on Prudký vŕšok hill. Quartz-carbonate vein with sulphides in schists of the Harmónia Group with disseminated galena, sphalerite, chalcopyrite and pyrite; No. 13 — village Častá, lower adit. Analogous to sample No. 12, Sb-sulphosalts — jamesonite and bournonite are represented in veinstone too; No. 14 — Sb-deposit Pezinok, bore hole KV—29, 97.2 m. Fine-grained galena on fissure in biotitic Palaeozoic phyllites; No. 24 — Gápeľ hill near the village Čavoj, Mandel adit. Quartz veins with carbonates with disseminated galena and sphalerite in gneisses of Palaeozoic age, partly in the Variscan granitoids; No. 28 — near former hotel Trangoška, at the road between the hotels Tále — Srdiečko. Quartz-barite veins galena, sphalerite and Sb-sulphosalts, chalcopyrite, pyrite etc. developed on the contact of Palaeozoic migmatites with Werfenian and Lower Triassic quartzites; Nos. 46, 47 — deposit Jasenie, Soviansko hill. Quartz veins with calcite, barite, galena, sphalerite and Sb-sulphosalts in migmatites and gneisses; No. 50 — village Špania Dolina. Chalcopyrite-tetrahedrite ore mineralization in the crystalline rocks (migmatites) and in overlying clastogene Permian (crystalline complex of the so-called Starohorské okno); No. 27 — Ostrá hill near village Hnúšťa. Galena-carbonate veinlet with ankerite in the Palaeozoic biotitic phyllites; No. 16 — village Rochovce, Dubina valley. Fine-grained galena with sulphides (chalcopyrite, pyrite, sphalerite) in quartz vein formed in the Upper Palaeozoic metamorphites.

The $^{206}Pb/^{204}Pb$ changes within the whole series of the analysed samples approximately from 17.9 to 19.0, i. e. by about 6 %. The change of $^{207}Pb/^{204}Pb$ ratio ranges from 15.62 to 15.72 (0.6 %), so that the distribution of points in the lower graph is along the horizontal axis rather dense. (It should be noted that the scale of $^{207}Pb/^{204}Pb$ ratios is intentionally "expanded" to make the variation of this ratio graphically more conspicuous.) On account of the scale of the axis of this graph (it differs 5,5 times) the experimental points form a field immediately adjoining the top part of the average evolution curve ($\mu = {}^{238}U/$

Table 2

Group 2. Deposits and ore accumulations in the rocks of the Spišsko-gemerské rudohorie Mts.

2.1 Vein ore mineralization of siderite-sulphidic formation

Sample No.	Locality	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
22	Betliar	18.837	15.676	38.993
3	Nižná Slaná	18.229	15.641	38.342
6	Slovinky, Dorotea adit	19.031	15.702	39.449
21	Slovinky	19.018	15.712	39.415
4	Poproč, Sb-deposit	18.568	15.698	38.887
48	Rákoš	18.364	15.633	38.463
49	Rákoš	18.345	15.651	38.492
2.2 Sulphidic syngenetic ore mineralization in the rocks of the Gelnica Group (in schists, phyllites, metabasites)				
10	Mníšek n. Hnilcom, Jalovičí vrch hill	17.996	15.646	38.188
7	Helcmanovce, bore hole HP-1	18.004	15.664	38.244
2	Smolník	17.993	15.666	38.137
17	Smolník	17.951	15.634	38.130
20	Smolník	18.070	15.633	38.251

Localization of samples: No. 3 — village Betliar. Sulphidic-carbonate vein with small galena crystals (to 1 mm) in Palaeozoic schists (Gelnica Group); No. 6 — village Nižná Slaná. Fine-grained galena aggregates in quartz vein intersecting the siderite and ankerite ore mineralization formed by metasomatism in the rocks of the Gelnica Group; No 21 — village Slovinky. Siderite-sulphidic deposit, Dorotea adit, 26th horizon. Quartz-carbonate veins with large galena crystals (to 1 cm) and with tetrahedrite; No. 4 — village Slovinky. Large (to 1 cm) galena monocrystal from sulphidic ore mineralization with traces of tectonic deformation in the rocks of the Gelnica Group; No. 22 — Sb-deposit Poproč, Agneša adit. Quartz vein with fine-grained sulphides, especially galena, which form a fine dispersion and chambers in the vein. Deposit is situated near intrusion of Gemeride granites; Nos. 48, 49 — village Rákoš. Sulphidic polymetallic ore mineralization (pyrite, chalcopyrite, galena, cinnabar) in the Palaeozoic schists near the contact of Gemerides and Veporides; No. 10 — Hutná dolina valley, Jalovičí vrch hill near the village Mníšek nad Hnilcom. Galena from quartz-carbonate vein intersecting stratiform pyrite ore mineralization in metabasites dynamically and hydrothermally altered; No. 7 — village Helcmanovce, bore hole HP-1. Galena from polymetallic syngenetic (?) ore mineralization in the Gelnica Group; Nos. 2, 17, 20 — village Smolník. Pyrite ore mineralization in chloritic phyllites of the Gelnica Group. No. 2. Large galena crystal from the vein intersecting pyrite ore mineralization. No. 17. Galena from quartz vein with carbonates and sulphides (galena and sphalerite) intersecting pyrite ore mineralization. No. 20. Galena from the fissures in chloritic schists filled up with carbonates with a small amount of pyrite and galena.

$/^{204}Pb = 9.74$). The uppermost points correspond roughly to the evolution curve with parameter 10.1 (this line is not shown in the graph). The ore lead of the

Table 3

Group 3. Ore mineralization in the area of Central Slovakian neovolcanites

3.1 Ore mineralization connected with the Hodruša intrusive complex (skarns, copper porphyric ores, stockwork-impregnated ore mineralization in granodiorite)

Sample No.	Locality	^{206}Pb/^{204}Pb	^{207}Pb/^{204}Pb	^{208}Pb/^{204}Pb
43	Vyhne — Klokoč, Fe-skarn	18.659	15.642	38.841
44	Zlatno, Cu-porphyric ore mineralization	18.826	15.668	38.945
45	Zlatno, Cu-porphyric ore mineralization	18.875	15.682	39.013
40	Banská Hodruša, Rozália mine, stockwork-impregnated ore mineralization	18.831	15.657	38.941
41	ditto	18.875	15.658	38.963
42	Banská Hodruša, Rozália mine, metasomatic ore mineralization connected with stockwork-impr. ore mineraliz.	18.825	15.666	38.952
37	ditto as 42	18.888	15.677	39.040

3.2 Vein and metasomatic polymetallic ore mineralization (type Banská Štiavnica) and vein silver-bearing quartz-carbonate ore mineralization (type Banská Hodruša)

Sample No.	Locality	^{206}Pb/^{204}Pb	^{207}Pb/^{204}Pb	^{208}Pb/^{204}Pb
33	Ban. Štiavnica, Ján vein	18.814	15.699	39.082
34	Ban. Štiavnica, Bieber vein	18.830	15.678	39.011
35	Ban. Štiavnica, Viliam vein	18.831	15.681	39.019
36	Ban. Hodruša, Rozália vein	18.856	15.691	39.058
38	Ban. Štiavnica, metasomatic ore mineralization	18.834	15.686	39.040
11	Ban. Štiavnica, vein ore mineralization	18.823	15.692	38.999
39	Ban. Hodruša, Všechsvätých vein	18.829	15.653	38.908
32	Tisovec, Magnetový vrch hill	18.764	15.666	38.932

Localization of samples: No. 43 — villages Vyhne — Klokoč. Small galena grains disseminated together with sphalerite, chalcopyrite, quartz and haematite in garnetic skarn. Hydrothermal mineralization superposed on magnetite skarn; No. 44 — Zlatno near Banská Hodruša. Bore hole, 1012 m. Small galena and sphalerite grains disseminated together with a small amount of chalcopyrite in skarn; No. 45 — Zlatno near Banská Hodruša. Bore hole, 882.5 m. Analogous to the sample No. 44; No. 40 — village Banská Hodruša — Rozália mine, 10th horizon, stockwork-impregnated, mostly galena-sphalerite ore mineralization in granodiorite between the veins Rozália and Bakaly; No. 41 — village Banská Hodruša — Rozália mine, 8th horizon, analogous to the sample No. 40; No. 42 — village Banská Hodruša — Rozália mine, bore hole K—5, fine-grained, mostly galena-sphalerite metasomatic ore mineralization in the blocks of carbonate-anhydritic sediments in granodiorite; No. 37 — village Banská Hodruša, Rozália mine, 8th horizon. Metasomatic galena-sphalerite ore mineralization in dislocated dolomitized limestones genetically probably connected with stockwork-impregnated ore mineralization; No. 33 — Banská Štiavnica, Ján vein, Michal shaft, 12th horizon, lower Pb-Zn zone. Quartz-barite vein filling with disseminated galena and light sphalerite. 6th mineralization period in the veins of the Štiavnica type; No. 34 — Banská Štiavnica, Bieber vein, Ferdinand adit, upper Pb-Zn zone. Coarse-grained polymetallic, mostly galena-sphalerite ore mineralization. 4th mineralization period; No. 35 — Banská Štiavnica, Viliam vein, Emil shaft, 3rd horizon, lower Pb-Zn zone. Coarse-grained, galena-sphalerite ore mineralization with raised chalcopyrite content, 4th mineralization period; No. 36 — village Banská Hodruša, Rozália vein, 4th horizon, copper zone, fine-grained galena, sphalerite and chalcopyrite disseminated in quartz veinstone. 2nd mineralization period in the veins of the Štiavnica type; No. 38 — Banská Štiavnica, near Alžbeta shaft, 12th horizon, metasomatic ore mineralization near Bieber vein. Fine-grained, galena-sphalerite ore mineralization in limestones altered during the process of metasomatism to dolomite, chlorite and serpentine minerals; No. 11 — Banská Štiavnica, galena from the vein polymetallic ores; No. 39 — village Banská Hodruša, Všechsvätých vein. Small galena and sphalerite veins disseminated in quartz-calcite veinstone. 5th period of mineralization in the veins of the Hodruša type; No. 32 — village Tisovec, Magnetový vrch hill. Quartz vein with galena in phyllitic schists near skarn ore mineralization. Ore mineralization is probably connected with neovolcanites (andesites).

Table 4

Group 4. Sulphidic ore mineralization in carbonate rocks (including magnesites)

Sample No.	Locality	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
8	Ochtiná, deposit Mária Margita	18.879	15.693	38.823
15	Poniky, Pb-deposit	18.860	15.676	38.830
1	Magnesite deposit Burda	18.882	15.693	38.798
18	Magnesite deposit Burda	18.865	15.674	38.781
26	Magnesite deposit Burda	18.883	15.688	38.824
30	Pohorelská Maša, deposit Lívius Samuel	18.854	15.671	38.786

Localization of samples: No. 8 — village Ochtiná, poor stockwork pyrite, sphalerite, galena ore mineralization in Carboniferous limestones; No. 15 — village Poniky near Banská Bystrica. Galena from fine-grained metasomatic ore mineralization in carbonate rocks of Mesozoic (Triassic ?) age near the Neogene volcanites; Nos. 1, 18, 26 — magnesite deposit Burda. Galena crystals from quartz veins in the magnesite bodies; No. 30 — village Pohorelská Maša, deposit Lívius Samuel. Fine-grained metasomatic galena ore mineralization in the Triassic limestones.

studied West Carpathian area thus originated before the deposition of ores in the rocks, i. e. sources with, on the average, similar U/Pb values. Also the "model" age calculated from the $^{207}Pb/^{206}Pb$ ratio according to formulae of the Stacey—Kramers' model (second stage) may represent an, on the whole, real genetic characteristic of the ore lead in the area studied.

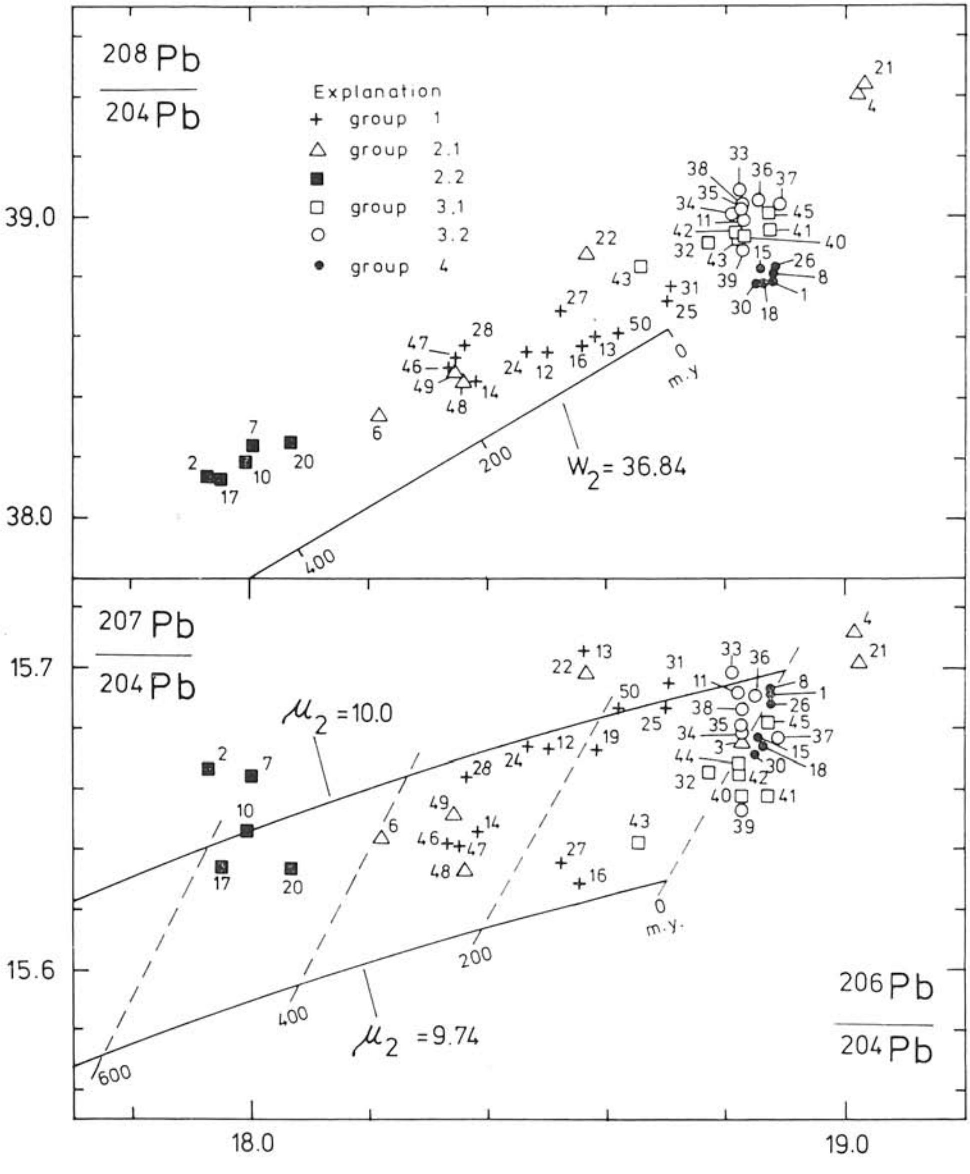

Fig. 2. Evolution diagrams of isotopic composition of lead according to Stacey — Kramers (1975) and results of galena analyses from deposits and ore indications of the West Carpathians. Numbers of samples in diagrams correspond to numbers in geological scheme and in the table.

Explanations: 1 — galenas from Tatro-Veporides; 2 — ore mineralization in the Spišsko-gemerské rudohorie Mts.; 2.1 — ore mineralization of siderite-sulphidic and antimonite ore formation in the Gelnica Group; 2.2 — syngenetic ore mineralization in the series of strata of the Gelnica Group; 3 — ore mineralization in the area of Central Slovakian neovolcanites; 3.1 — ore mineralization connected with the Hodruša intrusive complex (skarns, copper porphyric ores, stockwork-impregnated ore mineralization in granodiorite); 3.2 — vein and metasomatic polymetallic ore mineralization (type Banská Štiavnica) and vein silver-bearing ore mineralization (type Banská Hodruša); 4 — sulphidic ore mineralizations in Mesozoic limestones and in carbonates of "magnesite band".

The $^{208}Pb/^{204}Pb$ ratio exhibits other relationships. The experimental points (upper graph) are located much higher than the corresponding average curve of Pb evolution, and the majority of them lie farther to the right of the zero point of this curve. The measurement values of the $^{208}Pb/^{204}Pb$ ratio can be described by an evolution curve which corresponds to a higher than 3.782 value of the Th/U ratio. Under these conditions the "model" age value derived from the $^{208}Pb/^{204}Pb$ ratio is unreasonable.

In determining the model age it is to be decided whether or not the value calculated (according to schemes of different authors) gives the true age of the paragenesis investigated. There are two types of anomalies: anomaly of B type (after the Bleiberg deposit) gives the model age of lead higher than is the age of mineralization (its age before regeneration); anomaly of J type (after the Joplin deposit in the U.S.A.) gives the Pb model age lower than is the age of paragenesis. The second anomaly is caused by the admixture of radiogenic lead entering the solutions before crystallization of Pb mineral, or by an abrupt increase in the amount of uranium relative to Pb content in the mother rock.

These anomalies complicate the geological interpretation of lead isotope data. In such cases other methods of investigation of Pb-bearing minerals should be looked for, which would provide a possibility or confronting the isotopic data with geological, tectonic and geochemical information.

According to information of Dr. V. Kátlovský, CSc. (Geological Institute SAV, Bratislava) and published data (Kucharič, 1972 and Cambel — Khun, 1983), the rocks of the West Carpathians are characterized by an increased and in many cases markedly varying Th/U ratio relative to the clarke ratio. Values were calculated from the measurements carried out on selected samples from the West Carpathian region — "ZK" samples (Geol. Zbor. — Geol. carpath., 5, 1982). In granitoids, the highest Th/U values have been found in the rocks of the Malé Karpaty Mts. (up to 6.5, mean value from 242 anal. — 4.8), the Suchý Mts. (9) and the Vysoké Tatry Mts. In Gemeride granites this ratio drops to 0.7.

In sedimentary-metamorphosed rocks the relations are inverse: the Th/U values in the rocks of the Malé Karpaty Mts. are normal (3.9 — see Tab. 5) or, in some cases, reduced (to 1.2—1.5) and anomalously high in the rocks of the Spišsko-gemerské rudohorie Mts. Thus, for example, this ratio is about 20 in graphitic schists and chlorite phyllite in the area of Smolník pyrite deposit. The U and Th contents in metasediments of the Malé Karpaty Mts. are listed in Table 5 (Cambel — Khun, 1983). Mean U and Th contents in the West Carpathian granitoids are given in Table 6 (Kucharič, 1978). The values published by Kucharič were obtained by regional radiometric measurements.

From the comparison of regional geochemical particularities of rocks with isotopic characteristics of the ore lead it can be preliminarily concluded that the deposits located in the Tatro-Veporide (mainly in Tatride) crystalline units derived their metal content predominantly from magmatic sources. On the other hand, in the Spišsko-gemerské rudohorie, where low-grade metamorphosed sedimentary rocks of variable lithology prevail, mobilization of metals from the Palaeozoic mantle rocks was more important for mineralization. However, decisive was the presence of Neoidic granitoids, whose existence in the Tatrides has not yet been proved.

The influence of the sedimentary mantle is observable to a certain extent also in the Malé Karpaty Mts., where the mantle rocks are more weakly metamorphosed. The two units, the Harmónia Group (Devonian — Middle Carboniferous) and the Pezinok-Pernek (Cambro-Silurian — Lower Devonian) Group are of relatively large extent. Unlike the Spišsko-gemerské rudohorie Mts., this mountain range is very rich in granitoids, which effected intensive metamorphism of the schistose mantle and thus also migration of Pb and mainly of U and Th as early as during the plutogenic metamorphic processes, even into complexes considerably distant from the centre of metamorphism. Simultaneously with the long-lived plutogenic metamorphism of rocks caused by the ascent of granitoid magma, isotopic composition of lead was also chang-

Table 5

Summarizing table of average contents of Th, U, K and the Th/U ratios in the crystalline rocks of the Malé Karpaty Mts. (Cambel — Khun, 1983)

		Productive zones			Outside zones		Black shales together	Gneises to phyllites	Granitoids
		Type B+C N=26	Type A N=36	Together N=62	Harmónia Group N=17	Together N=40	N=102	N=27	N=242
Th	$\overline{x}$	3.58	3.07	3.23	9.20	7.66	4.98	8.4	9.1
U	$\overline{x}$	19.69	12.46	15.15	4.30	4.27	11.10	2.3	1.9
K	$\overline{x}$	1.28	1.10	1.18	2.79	2.68	1.77	2.4	3.0
Th/U	$\overline{x}$	0.87	1.35	1.15	2.59	2.42	1.63	3.9	4.8

Note: Mean Th/U values do not represent ratio of averages Th and U, because the variation coefficient Th/U is high (over 100 %).

Table 6

K, U, Th — contents in granitoids of the West Carpathians (Ľ. Kucharič, 1978)

	N	K(%)	U(p.p.m.)	Th(p.p.m.)	Th/U
Suchý + Magura Mts.	22	3.38	3.09	8.05	2.61
Žiar Mts.	27	3.00	2.95	9.02	3.05
M. Fatra Mts.	23	2.75	4.91	14.39	2.93
V. Fatra Mts.	46	3.18	3.82	8.49	2.22
N. Tatry Mts. — West Prašivá	38	2.88	3.38	14.12	4.17
N. Tatry Mts. — East Kráľova hoľa	52	2.50	3.87	14.98	3.87
Kohút type — Veporides	141	2.90	3.48	19.08	5.48
Hrončok	54	3.91	3.35	12.12	3.62
Hnilec type — Gemerides	148	2.76	7.17	8.98	1.25
Poproč	88	3.75	3.60	14.82	4.23
Betliar	17	3.26	3.44	12.82	3.72

ing (Cambel — Khun, 1983). This accounts for a high contamination of ore lead and the partial decrease of its model age (samples 25, 31).

1. Deposits of the Tatro-Veporides (group 1). The data on the deposit groups of the Tatro-Veporides are plotted in two evolution diagrams of $^{206}Pb/^{204}Pb$ — $^{207}Pb/^{204}Pb$ and $^{205}Pb/^{204}Pb$ — $^{208}Pb/^{204}Pb$ in Fig. 2. It should be noted that the fields of the individual groups can be well correlated. The deposits in the crystalline Tatro-Veporides are characterized by a rather wide scatter of isotopic ratios. The values of the "model age", which can be defined directly from the graph after the position of the experimental point relative to isochrons 0, 200 and 400 Ma, lie approximately within the interval of 330 to 100 Ma.

With respect to the model age the deposits and occurrences of ores can be divided into several groups. The group of deposits with model ages of 320—300 Ma may be assumed to correspond to the main phase of Variscan plutonism in age (samples 28, 46, 47; a similar age is reported by Kantor — Rybár, 1964, for the deposits Dolná Lehota — Dve vody, Nízke Tatry Mts. i. e. 320 Ma).

The model ages 270—240 Ma of the second group can be supposed to indicate the late Variscan or post-orogenic processes and hydrothermal aftermaths of Variscan plutonism (samples 12, 13, 14, 24) (Kantor — Lom deposit, Dolná Lehota — Ždiar, Nízke Tatry Mts.). The model ages of this group of deposits might have already been influenced by contamination of lead from the environments.

The galena from the Špania Dolina deposit (sample 50) shows a greater reduction of the model age, probably affected by the admixture of radiogenic lead from Permian sediments.

Most difficult to interpret are samples with model ages of 200 to 100 Ma (samples 27,16 and Kantor's samples from Malé Železné — 200 Ma — Nízke Tatry Mts., and Chvojnica — 160 Ma — Malá Magura Mts.) In the case of galena from the Veporides the influence of Neoidic magmatism cannot be excluded (e. g. Rochovce, sample 16 — 100 Ma). The lower model ages of lead in Pb-Zn deposits of the Malé Karpaty Mts. (samples 25,31) have been mentioned above and interpreted in terms of a J-anomaly.

As is seen, the interpretation of the model ages of galenas from the Tatro-Veporides is not unequivocal and four alternative explanations can be proposed:

a) In the studied areas of the West Carpathians (Tatro-Veporides) mineralization processes occurred in Variscan to post-Variscan times, being associated with the intrusions of younger granitoids during the Permian.

b) Alpine processes may have caused regeneration of older ore concentrations or remobilized dispersed ore elements in rocks of different age. In this case the isotopic composition of Pb on some deposits of the Core mountains might be explained as a mixture of old and younger lead remobilized during later Neoidic metallogenic processes.

c) It cannot also be excluded that the genesis of ores in the crystalline West Carpathians was due to young processes, intimately associated with the Neoidic, granitoids, mainly in the Veporides.

d) The possibility that contamination with radiogenic lead gave rise to J-anomalies cannot be omitted.

2. The deposits of the Spišsko-gemerské rudohorie Mts. (group 2) exhibits an even broader spectrum of the dispersion of isotopic characteristics. The "model age" of Pb from deposits of siderite-sulphidic formation varies between 380 (Nižná Slaná, sample 6) and zero (Betliar, sample 3); some negative values have also been ascertained (Slovinky, samples 4, 21). The two last samples are according all signs J-anomalous, very likely due to the presence of radiogenic lead, which separated from rocks having a markedly content of both U and Th. The anomalous model age of the sample from Betliar is probably caused by its derivation from an area where veins with uranium minerals occur. In the neighbourhood of Nižná Slaná (sample 6), the B anomaly in the sense of Houtermans is involved. Near the siderite deposit in the Gelnica Group, interstratified layers of earlier syngenetic polymetallic mineralization have been found during exploration. It is thus no wonder that the high B anomaly is caused by re-transportation of Lower Palaeozoic primary mineralization into the siderite deposit, but probably with an admixture of younger lead (380 Ma).

The Variscan model ages of lead from the Poproč deposit (250 Ma) and the Rákoš deposit (260, 320 Ma) are interesting. The former deposit is situated near a large granite body and the latter near the Veporides, i. e. in the area of granitoid plutonism where both the Variscan and the Gemeride Neoidic plutonisms may have exerted some influence. These two samples have relatively high isotopic ages, which can indicate the time of metal separation in process of granites intrusion.

Four samples that have a close relation to the exhalative-sedimentary mineralization in the Gelnica Group (Smolník, samples 2, 17, 20, Mníšek nad Hnilcom, sample 10) show a special character. According to the isotopic composition of Pb, they represent a clearly defined group. The lead yielded the lowest isotopic ratio values in the West Carpathians and the highest model ages (600—480 Ma).

Similar values for this type of mineralization have been published by Kantor — Rybár, 1964. The most likely explanation of these data is that the syngenetic ore lead was mobilized from the rocks of the Gelnica Group into the transecting veins. This conception virtually does not limit the age of the Pb vein mineralization. Very slight contamination with younger lead (definitely younger than 500 Ma) indicates rather Early Palaeozoic age of this mineralization, which might be very near to that of Cambro-Silurian syngenetic pyrite ore. According to the isotopic characteristics, the lead studied is a typical lead of the crust or even upper crust (Doe —Zartman, 1979) and its origin does not seem to have been associated with basic magmatism as was the genesis of pyrite mineralization. The lead of pyrite deposits in the Kuroko area in Japan has essentially lower values of ^{207}Pb/^{204}Pb ratio (Sato — Sasaki, 1973; Sato et al., 1981) although it is younger than Pb from Smolník.

3. Lead in galena deposits in the Štiavnica—Hodruša ore district (group 3) is distinguished by several isotopic features. The ^{208}Pb/^{204}Pb ratio (upper graph) is very conspicuous, and the experimental points of ^{206}Pb/^{204}Pb — ^{207}/Pb/^{204}Pb are concentrated near the zero isochron. The model age of Pb near to zero well agrees with the Neogene age of mineralization, which points to

a magmatic, well unified, volcanogenic source of ore lead (and other metals). The two diagrams show that the isotopic ratios of Pb of geologically different mineralization types have similar values. The total range, except for sample 43, exceeds the analytical error only 3 to 4 times. In contrast, the dispersion of points is fairly characteristic (see Fig. 3, magn. 3×). Galena from Fe skarn (sample 43) is of a specific character. In both graphs the distribution of points shows a definite trend perpendicular to the axis ^{206}Pb/^{204}Pb. On the basis of this trend the points or dispersion fields of mineralization types can be readily discriminated. Mineralizations connected with the Hodruša intrusive complex (subgroup 3.1) — porphyry-copper ore of Zlatno type and impregnated-stockwork ore in granodiorite — separate distinctly enough from polymetallic vein and metasomatic mineralizations of Banská Štiavnica type on the one hand, and from the argentiferous veins of Banská Hodruša type, on the other (subgroup 3.2). The minor division in the isotopic composition of ore lead probably reflects chemical differences in the Pb, U and Th contents of

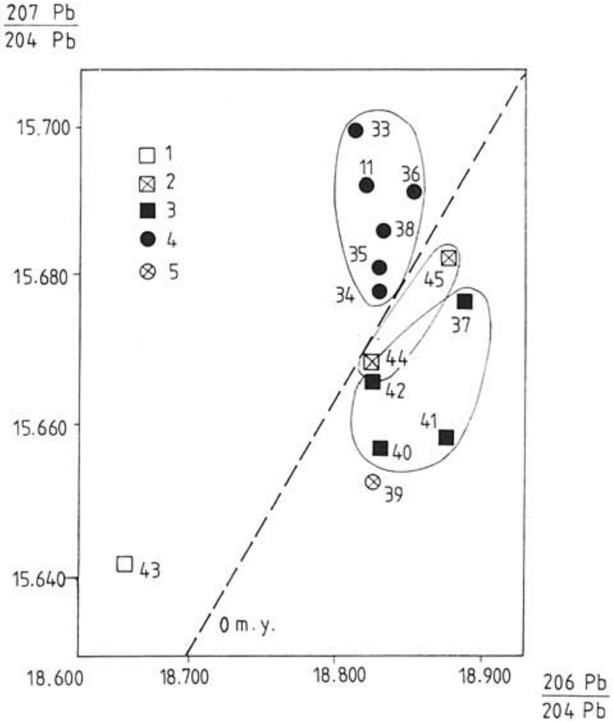

Fig. 3. Detail from Fig. 2 with denoted values of isotopic ratios of galenas (group 3) from various types of ore mineralization in Štiavnica—Hodruša ore district and its surroundings (magn. × 3).

Explanations: 1 — Vyhne — Fe-skarn; 2 — copper porphyric ores — Zlatno; 3 — stockwork-impregnated ores in granodiorite; 4 — polymetallic ore mineralization of the Štiavnica type; 5 — silver-bearing ore mineralization of the Hodruša type.

the granodiorite and andesite-dacite and/or rhyolite magmas with which the discussed mineralization types are connected. The differences in the isotopic composition of ore lead might also be due to the contamination of magmatic lead with lead contained in pre-Neogene sedimentary carbonate rocks. The latter theory is supported by the more evident change of all three isotopic ratios in galena from Fe skarn (sample 43). Interesting but now open question is possible role of granodiorite as a source of anomalous lead. Sporadic indications of uranium mineralization on Štiavnica and Hodruša veins occur in a very close relation with the granodiorite wall rock.

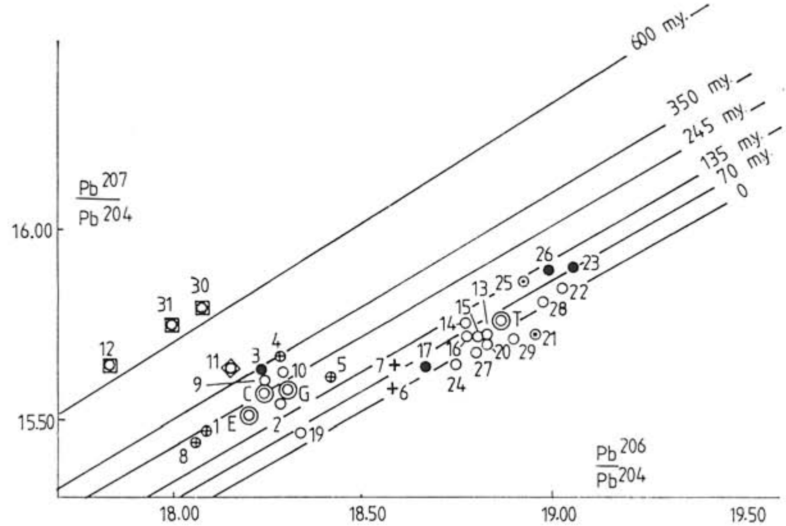

Fig .4. Holmes — Houtermans' isochron diagram.
Mean values: T — Tertiary; C — crystalline complex (West Carpathian); E — England (Cornwall — Devon), Variscan; G — Germany, Variscan. Localization of samples is given in Tabs. 1—4.

The above characteristics of lead isotopes permit us to put forwards the following assumptions of genetic relationship between the individual mineralization types in the Štiavnica—Hodruša ore district.

a) The Fe skarns and the superimposed polymetallic mineralization (sample 43) occupy a special position and are not connected either in genesis or in age with other ore types, including the porphyry copper ores, which are developed mainly in skarns.

b) The impregnated and metasomatic mineralizations in granodiorites (samples 40, 41, 42 and 37) are more closely related genetically to the porphyry copper ores (samples 44, 45) than to the Štiavnica and Hodruša vein types. Their dispersion fields show similar characters and partly overlap (Fig. 3).

c) The relatively great difference in the ages of Pb of the Štiavnica ore type (samples 11, 33 to 36, 38) and the Hodruša type (sample 39) suggests that two separate mineralization types are involved (Fig. 3).

d) The isotopic composition of lead from deposits in carbonate rocks (group 4) was rather a surprise. It is near to the composition of lead from Neogene deposits in the Štiavnica—Hodruša district. Sulphidic mineralization in carbonate rocks is usually characterized by heterogeneity and variation of isotopic Pb composition of different degrees (Delevaux — Doe, 1972; Doe — Zartman, 1979; Köppel — De-Schroll, 1979; Černyšev — Pavlov, 1980). The accordance of isotopic composition we have observed in the analysed samples is the more suprising, if we realize that the sampling localities are widely spaced and occur in different geological units of the West Carpathians. This fact can be explained in terms of endogenous magmatism which in Neogene times was active in all areas of the occurrence of this mineralization. According to Kantor (1962) a higher age (120 Ma) has been yielded only by galena from Ardovo, which may indicate a genetic connection with the Gemeride granitic rocks.

In conclusion, we can only repeat that the data on the lead isotopes permit in many cases to draw only general or preliminary conclusions, but despite this the information they have provided on the genesis of ore deposits in the West Carpathian region is of great value. Some of the conclusions will doubtless be concretized and made more precise in the future by more detailed investigation of the most relevant deposits e. g. Smolník and Poniky in the neovolcanics of central Slovakia, but especially of the deposits in the Veporide/Gemeride boundary zone.

Translated by H. Zárubová

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