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The comparison of strata-bound massive sulfide deposits using the fuzzy-linguistic diagnosis of the Zlaté Hory deposits, Czechoslovakia, as an example

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Abstract. The Zlaté Hory ore deposits – as an example of volcanogenic, strata-bound, massive, base-metal sulfides occurring in the Devonian formations of the Jeseníky Mts. – are compared with distinctive Phanerozoic types representing this type of ore deposit, i.e., with Kuroko-type, Rosebery-type, Besshi-type and Cyprus-type deposits. The results of comparison performed with fuzzy-linguistic diagnosis indicate close resemblance of the Zlaté Hory deposits to Rosebery-type massive sulfides with regard to primary features; however, individual features point to certain original similarity with Kuroko-type deposits, too. The metamorphic history of the ore deposits studied was similar to that of the Rosebery and Besshi types.

Numerous studies (Gilmour 1971; Hutchinson 1973; Sawkins 1976) and many others cited in Mitchell and Garson (1981), Sawkins (1984), and Hutchison (1987) are devoted to the problem of comparing and classifying volcanogenic massive sulfides. A whole range of criteria is summarized in these studies. Thanks to them, every individual strata-bound massive sulfide deposit can be described in detail. The authors, inspired by the abundance of criteria as well as by classifications of ore deposits applying a mathematical approach (Sattran 1979), compared the Zlaté Hory massive sulfide deposits with Phanerozoic prototypes of volcanogenic massive sulfides using the fuzzy-linguistic diagnosis (Kaufmann 1975). The Zlaté Hory ore deposits, assumed to be of submarine-exhalative origin (Pouba and Ilavský 1986), are ranked among the most important base-metal and copper ore sources in Czechoslovakia, having estimated reserves of 203 kt Cu, 714 kt Zn, and 174 kt Pb (Vaněček et al. 1985).

The Zlaté Hory strata-bound massive sulfide deposits

Geologic setting

The Zlaté Hory ore district is situated in the northern part of the Jeseníky Mts., i.e., close to the NE margin of the Bohemian Massif. The orebodies occur within a volcano-sedimentary formation approximately 1,600 m thick composed of pelitic schists, quartzites, greenschists, keratophyres, and minor marbles. The age of the formation is considered to be Devonian since Siegenian fossils are found in the basal quartzites. To the east this formation is overlain by Culm sediments of Famenian-Tournaisian age (Dvořák et al. 1977; Fig. 1). The Devonian of the Jeseníky Mts., which is intricately folded and simultaneously altered to greenschist facies during the Sudetic phase of the Variscan orogeny (Rajlich 1976), represents the eastern equivalent of the ore-bearing Rhenohercynian belt comprising also Rammelsberg and Meggen polymetallic deposits according to Pouba and Sattran (1980) and Sawkins and Burke (1980).

The ore deposits of the Zlaté Hory district form an arched N-dipping structure about 10 km long (Pouba and Ilavský 1986; Fig. 1). Individual orebodies are predominantly situated in quartzites and/or quartz keratophyres underlying pelitic schists. Three principal types of orebodies are developed within the Zlaté Hory district, i.e.,

a) stratiform galena-sphalerite-chalcopyrite-pyrite orebodies,
b) chalcopyrite-pyrite stratiforms, and
c) cross cutting systems of chalcopyrite-pyrite-quartz veins and veinlets.

Stratiform orebodies of types (a) and (b) usually have deformed tabular or lenticular shapes. The stratiform galena-sphalerite-chalcopyrite-pyrite ores are found in western and eastern parts of the district; both remaining ore types are mined in the southern part of the Zlaté Hory ore district (Čabla et al. 1979; Fig. 2).

Mineralogy

Pyrite, sphalerite, chalcopyrite, galena and pyrrhotite are the major constituents of the Zlaté Hory ores. Common accessories are magnetite, arsenopyrite, tennantite, chalcocite, covellite, Ti-oxides, and native Au and Bi. Among the nonmetallic minerals quartz dominates; however, carbonates, barite, and phyllosilicates are abundant, too. Barite often occurs as separate lenses in the vicinity of stratiform orebodies (Fojt 1968; Havelka 1974; numerous studies cited in Čabla et al. 1979 and Pouba and Ilavský 1986).

The ore minerals within the Zlaté Hory stratiform orebodies form either parallel streaks and bands generally conforming to the host-rock schistosity, or disseminated to massive accumulations. The majority of the ore minerals have crystalline structures; a colloform structure is shown by pyrite formed by supergene alteration of pyrrhotite (Marek 1982). However, some colloform pyrites are interpreted as relicts of premetamorphic pyrite form (Havelka 1974).

The sulfide ores were recrystallized and partly mobilized during regional metamorphism (Fojt 1965, 1968; Havelka

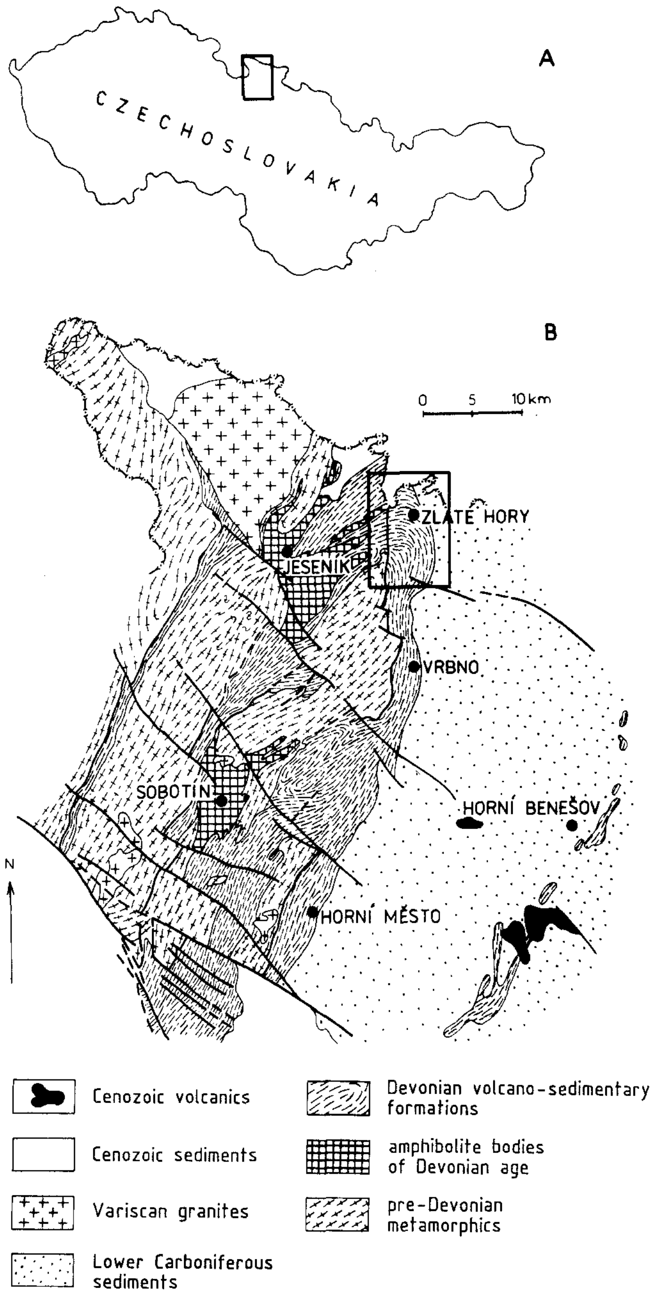


Fig. 1. **A** Geographic position of the Jeseníky Mts., Czechoslovakia. **B** Geologic map of the Jeseníky Mts.; rectangle marks the Zlaté Hory ore district

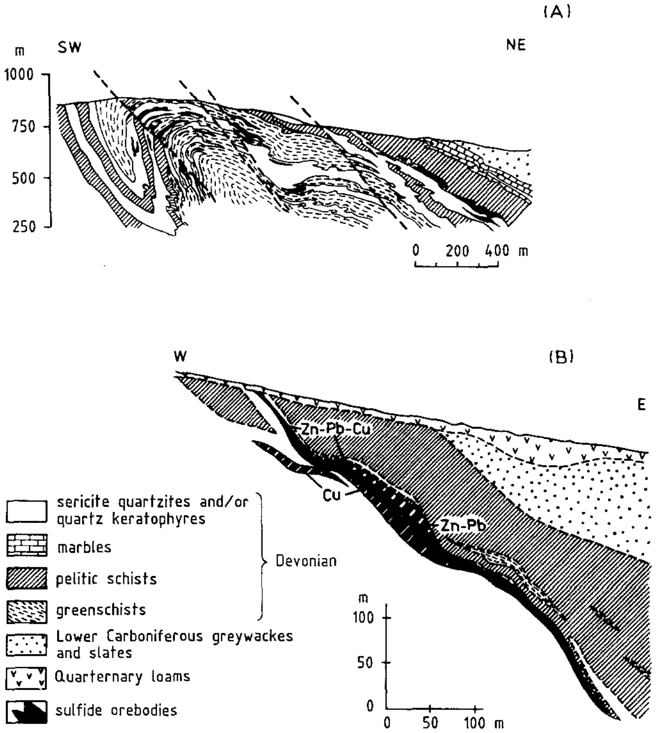


Fig. 2. **A** Cross section through the central part of the Zlaté Hory ore district. **B** Cross section through the Zlaté Hory East deposit. Both figures after Čabla et al. (1979)

1974). The differences between the contrasting structural types, recognized in the variety of the Zlaté Hory ores, indicate that the metamorphic effects were quite unevenly distributed within the orebodies. A very fine grained and finely banded ore (containing sphalerite poor in Fe) is considered to have a close to primary, i.e., premetamorphic, appearance. In contrast, massive and usually medium grained ore (having Fe-enriched sphalerite) probably formed during regional metamorphism of the latter (Cílek et al. 1985).

Geochemistry

The Cu ores, situated in lower stratigraphic ore-bearing sequence of the Zlaté Hory district (Fig. 2), are composed of sulfides rich in Se and poor in Ag; the Zn-Pb ores, overlying the latter, are depleted in Se and enriched in Ag and Au (Hoffman et al. 1977). Pyrites found in zinc-lead ores are characterized by Co/Ni values varying from 0.1 to 3.5; on the other hand, much higher Co/Ni ratios (8.0–22.0) are shown by pyrites from copper ores (Kvaček et al. 1984).

The Zlaté Hory sulfide sulfur isotope compositions vary mostly from -10.0 to $+5.0‰\ \delta^{34}S$ (most values lie between -5.0 and $-3.0‰\ \delta^{34}S$); barites of the Zlaté Hory ores usually display values within limits of $+18.0$ and $+26.0‰\ \delta^{34}S$ (Hladíková et al. 1989).

Outline of genetic concepts

The hypotheses concerning the origin of the Zlaté Hory strata-bound massive sulfide deposits comprise both epigenetic origin related to the Variscan granite intrusions and syngenetic origin related to submarine exhalations connected with Devonian volcanic activity (Pouba and Ilavský 1986).

Havelka et al. (1964), Pouba (1971), and Čabla et al. (1979) advocate the concept of volcanogenic origin; the latter authors regard the primary composition of the ore-forming solutions to be similar to seawater. Alteration of the host rocks by seawater-derived hydrothermal fluids is indicated by the occurrence of Ce-depleted greenschists within the ore-bearing, volcano-sedimentary formation (Patočka 1987). Recent investigations on sulfur isotopes revealed that both the Devonian seawater sulfate and accessory pyrite of the host rocks are principal sources of ore-forming sulfur solution; the role of the juvenile sulfur is regarded to be negligible (Hladíková et al. 1989).

The Zlaté Hory deposits compared with distinctive types of strata-bound, volcanogenic, massive sulfides of Phanerozoic age

The geochemistry of convergent-plate-margin basalts was identified in the Zlaté Hory ore district greenschists by Fišera et al. (1973). Jakeš and Patočka (1982) suggested that the Devonian volcanics of the Jeseníky Mts. display an approximately NS trending change from dominantly tholeiitic composition to dominantly calc-alkaline and/or alkaline. Mafic metavolcanics of the Zlaté Hory ore district were interpreted by Patočka (1987) to be equivalents of primitive island-arc basalts. Minor-element geochemistry of pelitic schists exposed in this area appears to indicate similarity between the source region of sedimentary precursors and ensialic island arc through the Devonian (Patočka 1988). According to Jelínek and Souček (1981) the Devonian basic to ultrabasic rocks of the amphibolite bodies of the Jeseníky Mts. reveal clear affinity to ophiolite complexes as well as some other metabasite bodies in the Sudetes (Pin et al. 1988).

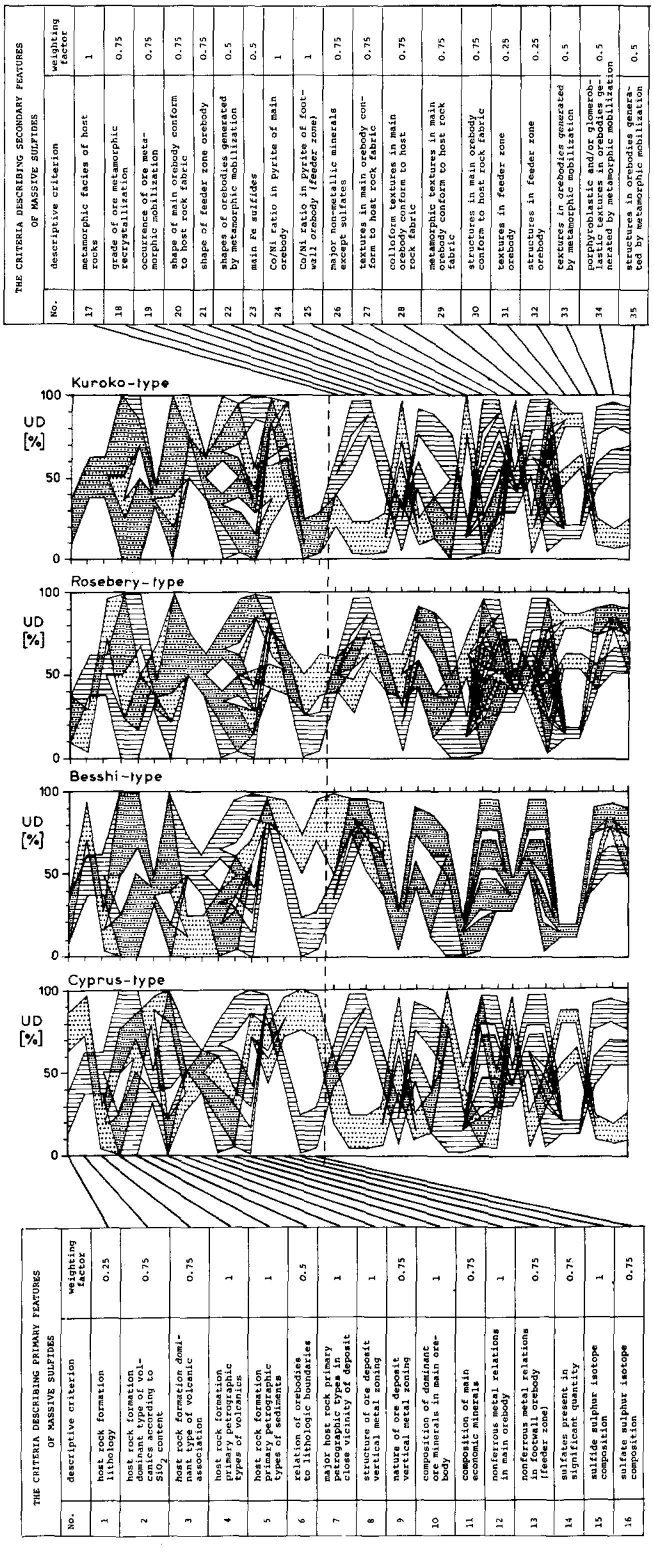
Consequently, it can be suggested that the Devonian in the Jeseníky Mts. seems to have several characteristics of the fossil-plate margin, as supposed earlier (e.g. Čabla et al. 1979). Sawkins and Burke (1980) also postulated an island-arc-type complex as the southern margin of the mid-European zone of crustal extension, which developed later to the Rhenohercynian zone. A Devonian back-arc basin linked to hypothetical southeastward subduction of the Sudetic ocean is presumed in the NE part of the Bohemian Massif (Pin et al. 1988).

According to Mitchell and Garson (1981), Sawkins (1984), etc., subduction-related tectonic settings are the most favourable for the occurrence of strata-bound, volcanogenic, massive sulfides. Provided that the Jeseníky Mts. Devonian and fossil convergent plate margin are related, the Zlaté Hory strata-bound deposits can be compared with distinctive examples of Phanerozoic massive sulfides. Three prototype examples of volcanogenic massive sulfide deposits are discerned based on composition of the ore and host rock associations, i.e., Cyprus-type, Besshi-type, and Kuroko-type deposits (e.g. Sawkins 1976; Mitchell and Garson 1981; Plimer 1985). The Rosebery-type deposit, usually supposed to be a metamorphosed analogue of a Kuroko-type deposit (Sawkins 1976), was included into the comparison as the fourth example since it was defined as an independent type by Solomon and Walshe (1979).

The set of 35 criteria, allowing the description of Kuroko-type, Rosebery-type, Besshi-type, and Cyprus-type massive sulfide deposits as well as the ones of Zlaté Hory, was assembled (Fig. 3). The features corresponding to the set of descriptive criteria characterizing the prototype examples were compiled from compendia and synthetizing works edited and written by Tatsumi (1970), Ishihara (1974), Strong (1976), Mitchell and Garson (1981), Sawkins (1984), Plimer (1985), Hutchinson (1987), and further literature cited therein. The characteristics of the Zlaté Hory deposits were compiled with the help of literature presented in the preceding chapter.

Method of comparison

In general, a comparison of the selected features, describing both the object compared (i.e., the Zlaté Hory deposits) and



THE CRITERIA DESCRIBING SECONDARY FEATURES OF MASSIVE SULFIDES

No.	descriptive criterion	weighting factor
17	metamorphic facies of host rocks	1
18	grade of ore metamorphic recrystallization	0.75
19	occurrence of ore metamorphic mobilization	0.75
20	shape of main orebody conform to host rock fabric	0.75
21	shape of feeder zone orebody	0.75
22	shapes of orebodies generated by metamorphic mobilization	0.5
23	main Fe sulfides	0.5
24	Co/Ni ratio in pyrite of main orebody	1
25	Co/Ni ratio in pyrite of footwall *orebody (feeder zone)*	1
26	major non-metallic minerals except sulfates	0.75
27	textures in main orebody conform to host rock fabric	0.75
28	colloform textures in main orebody conform to host rock fabric	0.75
29	metamorphic textures in main orebody conform to host rock fabric	0.75
30	structures in main orebody conform to host rock fabric	0.75
31	textures in feeder zone orebody	0.25
32	structures in feeder zone orebody	0.25
33	textures *in orebodies generated* by metamorphic mobilization	0.5
34	porphyroblastic and/or glomeroblastic textures in orebodies generated by metamorphic mobilization	0.5
35	structures in orebodies generated by metamorphic mobilization	0.5

THE CRITERIA DESCRIBING PRIMARY FEATURES OF MASSIVE SULFIDES

No.	descriptive criterion	weighting factor
1	host rock formation lithology	0.25
2	host rock formation dominant type of volcanics according to SiO_2 content	0.75
3	host rock formation *dominant* type of volcanic association	0.75
4	host rock formation primary petrographic types of volcanics	1
5	host rock formation primary petrographic types of sediments	1
6	relation of orebodies to lithologic boundaries	0.5
7	major host rock primary petrographic types in close vicinity of deposit	1
8	structure of ore deposit vertical metal zoning	1
9	nature of ore deposit vertical metal zoning	0.75
10	composition of dominant ore minerals in main orebody	1
11	composition of main economic minerals	0.75
12	nonferrous metal relations in main orebody	1
13	nonferrous metal relations in footwall orebody (feeder zone)	0.75
14	sulfates present in significant quantity	0.75
15	sulfide sulphur isotope composition	1
16	sulfate sulphur isotope composition	0.75

Fig. 3. Fuzzy-linguistic graphs of the diagnosis of the Zlaté Hory deposits compared with that of the four volcanogenic, strata-bound, massive sulfide, prototype examples. UD, universe of discourse, i.e., the ordinary set of all possible values corresponding to diversity of features belonging to every single descriptive criterion. Striped fields indicate the UD spans for features characterizing the Zlaté Hory deposits, dotted ones show the same for each particular diagnostic standard (i.e., massive sufide prototype). Metamorphism-independent (primary) features and metamorphic (secondary) ones are divided by dashed vertical line

representative standards of the object-embracing class (i. e., the four massive sulfide prototypes) according to a uniform criteria set, is usually applied for the purpose of finding out the degree of object similarity to the standard.

The selected standard features (characteristics), corresponding to every single criterion (Fig. 3), have to be evaluated, i. e., numerical or linguistic values have to be attributed to them. These values form an evaluating scale; the span of it is given by feature diversity – shown by standards – according to each single criterion. An ordinary set of all possible values that may be taken into account is usually termed "reference set" or "universe of discourse" (i. e., UD; for details see, e. g., Kaufmann 1975).

Generally, the features can be either more or less quantifiable or not quantifiable at all as follows:

a) The features of more or less quantifiable character can be evaluated by comparison with arbitrary values or appropriate intervals of corresponding continuous or discrete numerical axis.

b) The features of nonquantifiable character are evaluated using rather vague and uncertain verbal notions. However, in the intuitive professional sense, the meaning of the notions is sufficiently comprehensible. The notions can be directly or indirectly related to some independently quantifiable base, becoming an evaluating scale in this case.

Some uncertainty can be expected for characteristics of purely quantitative contents, too. This is a case when given conditions do not allow the evaluation of the features exactly and/or unambiguously. A simple example is the evaluating scale of linguistic terms "small", "medium", and "high". All belong to the descriptive criterion "height", i. e., they are utilized for describing a quantifiable parameter. Then, instead of the deterministic point value, the interval one is more appropriate for the given level of our model imaginations.

The mentioned way of feature evaluation can be generalized by both numerical and linguistic variables and fuzzy subsets as their common quantifier (Zadeh 1965). In the sense of fuzzy characteristics, the notion of the linguistic variable dominates that of the numerical variable, which may be understood as a special case (cf. the notions of "characteristic" and "membership" functions describing ordinary and fuzzy subsets; see Zadeh 1965, Kaufmann 1975). The necessary mathematical background for the construction of the model for evaluation is summarized in the Appendix.

The different weights of single descriptive criteria and corresponding characteristics as a matter of course are given by specific weighting factors. The factor is equal to one when the criterion under question is of the selective particular value (i. e., all standards display specific features corresponding to the single criterion). On the contrary, the weighting factor equals zero when the criterion is of the same descriptive value for all entries of the diagnostic model (i. e., according to the single criterion all standards are identical); in this case it is preferrable to exclude corresponding characteristics from the X vector. Between both extreme situations mentioned, there can be several combinations of specific and identical features corresponding to each individual criterion; the number of combinations depends on the number of standards described. The comparison dealing with four standards only involves three possible combinations when the ratios of specific and identical characteristics are 3:1, 2:2, and 1:3. Thus, the descriptive criteria were evaluated by weights expressed as quantities of 1, 0.75, 0.5, 0.25 and 0 (Fig. 3).

The method described is called here fuzzy-linguistic diagnosis. It is unnecessary, however, to understand the word "linguistic" literally; there are several reasons for its use:

1. It is practically a universal terminology.

2. It distinguishes the way of evaluation of the objects under question from that usually applied for ordinary numerical quantities.

3. A good deal of model variables (i. e., descriptive criteria and corresponding features) here are really verbally evaluated factors, e. g., "the grade of metamorphic recrystallization of ore is strong, medium, weak, not apparent" etc. On the other hand, normal numerical values as elements of continuous numerical axis have to be included into this notion as well. The quantifying roles of the notions "universe of discourse" and "fuzzy subset" unify these different views and thus enable the full exploitation of all advantages of this nontraditional modelling approach.

Discussion

The results of the comparison between the Zlaté Hory deposits and the four prototype examples of volcanogenic massive sulfides achieved using fuzzy-linguistic diagnosis are summarized in Table 1 and Fig. 3.

It has to be pointed out that the features characterizing the Kuroko, Rosebery, Besshi, and Cyprus types as well as the Zlaté Hory deposits (Fig. 3) can be arranged into two groups. The first group comprises features – corresponding to criteria 1–16 – involving potential effects of regional metamorphism either on a small scale or not at all. In contrast, the second group of features – corresponding to criteria 17–35 – imply metamorphic overprinting of ores and host rocks, or even more, they are considered as products of it. As the first group describes more or less primary nature of the volcanogenic strata-bound massive sulfides, it is called primary, too. The other one dealing with the metamorphic character of deposits is secondary. That is why the results of primary and secondary features are presented separately in Table 1; results for undivided sets of features are also included. From the viewpoint of the original similarity between the Zlaté Hory deposits and any of the four massive sulfide prototypes the primary feature sets are the most important for comparison.

The left half of Table 1 displays the fuzzy-linguistic results of the diagnostic model, named membership degree (MD). Distinct maximum or minimum values (1 or 0) of the membership degree denote seeked resemblance between the Zlaté Hory deposits and all of the four distinctive massive sulfide types. These values were obtained by fuzzy-linguistic comparison taking into account all members of either primary or secondary feature sets (or undivided ones) simultaneously.

In Fig. 3, graphs corresponding to the universe of discourse (UD) spans for all selected features, describing any of the standards mentioned and the Zlaté Hory deposits, are presented. Every graph is constructed as an envelope of the parallel set of UD span abscissas whose lengths correspond to the weighted contribution of single features to the diag-

Table 1. Results of fuzzy-linguistic diagnosis of the Zlaté Hory compared with that of the four distinctive strata-bound massive sulfide types; values for primary, secondary, and undivided sets of features are shown separately. MD, membership degree of the diagnostic model output taking into account all members of either primary or secondary (or undivided) feature sets simultaneously. SD, similarity degree with regard to separate comparison of individual features

Diagnostic standard	MD			SD (%)		
	Primary feature set	Secondary feature set	Undivided feature set	Primary feature set	Secondary feature set	Undivided feature set
Kuroko-type	0	0	0	71	34	57
Rosebery-type	1	1	1	69	60	64
Besshi-type	0	1	1	58	82	71
Cyprus-type	0	0	0	43	28	35

noses of both the standards and the object compared. The areas of overlap on the UD graphs of each standard and the Zlaté Hory deposits as well as the areas of every standard UD graph were measured. The ratios of areas mentioned, which express the similarity between the Zlaté Hory deposits and each of the four massive sulfide types with regard to separate comparisons of individual features, are displayed as relative values – arbitrarily called "similarity degree" – in the right half of Table 1.

Conclusions

The comparison of the Zlaté Hory strata-bound ore deposits with Kuroko-, Rosebery-, Besshi-, and Cyprus-type volcanogenic massive sulfide ores based on selected sets of features (Fig. 3) was performed using the fuzzy-linguistic diagnosis. The features regarded as more or less independent of regional metamorphism and the metamorphic-related ones (i. e., primary and secondary features) were taken into account in the diagnosis both as separate sets and as an undivided one. High membership degree (MD) values obtained by fuzzy-linguistic simultaneous comparison of all members of either separate or undivided feature sets indicate that the Zlaté Hory deposits display close resemblance to Rosebery-type massive sulfides. As to the MD values resulting from the secondary and undivided feature sets, these ore deposits are similar to Besshi-type deposits, too (Table 1). However, provided that individual features are compared separately, the Zlaté Hory deposits show some similarity to Kuroko-type deposits with regard to primary features and to Besshi-type deposits according to secondary features (Fig. 3 and Table 1).

The results from the comparison of metamorphism-independent features imply an original similarity of the Zlaté Hory deposits to Rosebery-type massive sulfides and possibly to Kuroko-type ones, too. Any traces of primary similarity of the investigated deposits to Besshi- and Cyprus-type deposits were not found. As the comparison of metamorphic features indicate, the metamorphic history of the Zlaté Hory deposits resemble that of Rosebery- and Besshi-type deposits.

Appendix

Variables and parameters X and Y of the fuzzy-linguistic model are supposed to take on certain values from their respective universes U and V either as numerical elements $x \in U$ and $y \in V$ or as evaluating terms in the form of fuzzy subsets $A \subset U$ and $B \subset V$ with membership functions $u_A(x)$ and $u_B(y)$, i. e.,

$$u_A(x)\colon U \to [0,1], \quad u_B(y)\colon V \to [0,1]. \qquad (1), (2)$$

In the former case $A \equiv x$ or $B \equiv y$ the membership functions (1) and (2) take the binary forms

$$u_A(x)\colon U \to \{0,1\}, \quad u_B(y)\colon V \to \{0,1\}. \qquad (3), (4)$$

A single point of the supposed mapping $X \to Y$ and its position on the corresponding Cartesian product $U \times V$ may be characterized by a conditional statement "if A for X, then B for Y", i.e.,

$$R_k\colon (X \Leftrightarrow A_k) \to (Y \Leftrightarrow B_k), \qquad (5)$$

where X may generally be an N-dimensional vector of independent variables and $k = 1, \ldots, M$ for M statements (5), the union of which may serve for the construction of a fuzzy relation S_{xy} as the projection of M independent $N+1$-tuplets (subjectively experienced and/or experimentally obtained information on $U_1 x \ldots. x U_n x V$ see Dubois and Prade 1980).

The relation S_{xy} thus forms the base for the fuzzy model $Y = Y(X)$, the statements (5) being constructed from the information on the character of the selected standards. Following, for example, Kaufmann (1975) the membership function of an ordered $N+1$-tuplet (x, y) is given as

$$u_S(x, y) = \underset{k}{\mathrm{MAX}}[\mathrm{MIN}[u_{A_k}(x), u_{B_k}(y)]], \qquad (6)$$

and the diagnostic-predictive role of the model describes the equation

$$B' = A'_1 \circ (A'_2 \circ (\ldots \circ (A'_N \circ S))), \qquad (7)$$

where $\circ$ is the symbol of the used composition of a general fuzzy subset A'_i (as the concrete evaluation of Xs with the same domains as As on corresponding Us) with the relation S (the subscript x, y is omitted for the sake of simplicity). For the currently used MAX-MIN composition the recursive equations for the computation of $u_{B'}(x, y)$, i. e., the membership function of the output of the model (Vrba 1984, 1986) follows the relational sequence of successively diminishing dimension.

$$S_k(N+1) = B_k \qquad (8)$$

$$S_k(i) = A'_i \circ (A_{ik} \circ S_k(i+1)); \quad i = N, N-1, \ldots, 1 \qquad (9)$$

$$B' = \bigcup_k S_k(1); \quad k = 1, \ldots, K, \qquad (10)$$

where $\cup$ stands for union and K represents the number of conditional statements (5). Thus,

$$u_{S_k(N+1)}(y) = u_{B_k}(y) \qquad (11)$$

$$u_{S_k(i)}(y) = \underset{x^i}{\mathrm{MAX}}\, \mathrm{MIN}\{u_{A'_i}(x^i), \mathrm{MIN}[u_{A_{ik}}(x^i), u_{S_k(i+1)}(y)]\}$$
$$i = N, N-1, \ldots, 1 \qquad (12)$$

$$u_{B'}(y) = \mathrm{MAX}[u_{S_k(1)}(y)]; \quad k = 1, \ldots, K. \qquad (13)$$

The recursive Eqs. (11)–(13) describe at the same time the computational algorithm, it is easy to prove their identity with the Eq. (7) for MAX-MIN composition and the preservation of all its rules performing simply the contrarecursive substitution.

For concrete description of membership degrees (MD) as particular values of corresponding membership function in points of their universes, the two-parameter parabolic equation is utilized (Vrba 1984)

$$u_A(x) = \begin{cases} 4(x - x_{A1})(x_{An} - x)/(x_{An} - x_{A1})^2, & \text{for } x \in \mathrm{Supp}\, A \\ 0 & \end{cases} \qquad (14)$$

where

$$\mathrm{Supp}\,A = \{x \mid u_A(x) > 0; \quad x \in A \subset U\} \tag{15}$$

and x_{A1} and x_{An} are boundary elements of Supp A on U.
The natural claims for construction of any linguistic-evaluating scale are

$$\bigcup_{r=1}^{R_x} \mathrm{Supp}\,A_r = U, \qquad \bigcup_{r=1}^{R_y} \mathrm{Supp}\,B_r = V, \tag{16), (17}$$

along with the stricter conditions

$$\exists\, r \in R_x : u_{A_r}(x) = 1, \qquad \exists\, r \in R_y : u_{B_r}(y) = 1 \tag{18), (19}$$

(R_x and R_y formally denote the corresponding r-sequences and at the same time their last and the highest members, respectively).

For the conclusive confrontation of diagnostic results Eqs. (10) and (13) with the previously stated and accepted evaluating scale of standard features on V the notion of distance between fuzzy subsets can serve, e. g., in the usual form of Hamming distance

$$\mathscr{H}_B^r = \sum_y |u_{B'}(y) - u_{B_r}(y)|, \tag{20}$$

where the subscript B along with the r-th fuzzy subset on V may also denote the binary function (Eq. 4) of an arbitrary element from V. The claim of

$$\underset{r}{\mathrm{MIN}}\,[\mathscr{H}_B^r] \tag{21}$$

suffers, however, from the rather small distinguishing ability between successive close terms of the scale. From this point its weighted modification

$$\bar{\mathscr{H}}_B^r = \sum_y |u_{B'}(y) - u_{B_r}(y)| \cdot u_{B_r}(y) / \sum_y u_{B_r}(y) \tag{22}$$

exhibits better properties (Vrba 1984). From the mathematical point of view, this modification is no longer a distance but, as a matter of fact, the applicability of Eq. (22) is in the given context purposelike rather than mathematically strict. To be correct, one can strictly use the notion of "distance" or "norm" but, nevertheless, a lot of counter examples can be given to prove their low validity (not to say invalidity) for the purpose. Eq. (22) is a heuristic adjustment to help the matter.

The different weights of single criteria and corresponding characteristics as a matter of course may be related by the quantity $g_i \cdot u_{Ai}(x^i)$ instead of $u_{Ai}(x^i)$. The weighting factor g_i for the i-th characteristic X^i fulfils the usual conditions

$$0 \leqq g_i \leqq 1 \qquad i = 1, \ldots, N \tag{23}$$

$$\sum_{i=1}^{N} g_i = 1 \tag{24}$$

and represents the modeller's opinion on the descriptive ability of the i-th feature.

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