STVDIA GEOLOGICA, XIV, 1978 (161-169)

A SUGGESTION FOR THE CLASSIFICATION OF TIN, TUNGSTEN AND MOLYBDENUM DEPOSITS ASSOCIATED WITH PLUTONIC ROCKS

MIROSLAV ŠTEMPROK
Czechoslovakia

INTRODUCTION

Ore deposits are large accumulations of certain elements in specific mineral associations. These associations may provide a suitable parameter for classifying tin, tungsten and molybdenum deposits associated with plutonic rocks.

The proposed classification is based on the observation that ore deposits are formed as products of distinct stages of mineralization. These sequences may represent independent inflows of solutions usually separated in time by intra-stage tectonic movements. The stage inflow may be composed of several sequential infiltration periods.

This proposal utilises the same principles of «formational» classification as that devised by LEVITSKII (1947) and RADKEVICH (1968) for tin deposits, DENISENKO (1975) for tungsten deposits and KHRUSHCHOV (1961) for molybdenum deposits. However, it differs in that it assumes a relatively simple composition of the products of each stage of mineralization, e.g. pure quartz, greisen or quartz-feldspar pegmatite assemblages. Virtually all the deposits considered here are composed of several overlapping stages of mineralization. Clearly defined and separate stages are rarely found in nature.

Economic mineralization is only associated with some of the stages of this classification but may be superimposed on the products of earlier barren stages of may be «diluted» by later ore-free stages. The main mineralization stages have a world-wide persistency and can easily be identified in deposits of any form and any geological age.

The first two sequences of the alteration stages differ depending on the geological environment in which they were active. For example in aluminosilicate rocks the early stages are commonly developed as pegmatites, replacement pegmatites or feldspathites, whereas in carbonate rocks various types of calcium or magnesium skarns are formed.

The sequence of stages involved in the formation of tin, tungsten or molybdenum deposits are as follows:

1. Pegmatitization:	This is characterized by the development of quartz, feldspar and mica assembiages. It is the first phase in the formation of pegmatites.
1a. Skarnization: (silicate stage)	In carbonate rocks this stage is characterized by the development of pyroxene, garnet or vesuvian. This stage constitutes a basis for the introduction of later mineral assemblages.
1b. Skarnization: (oxide stage)	In silicate skarns this stage is characterized by the development of magnetite.
2. Feldspathization:	Results in the development of replacement complexes in pegmatites (sodium or lithium metasomatism) or albitization in igneous rocks. Ore mineralization may be related to this stage.
3. Quartz formation and silicification:	Quartz fissure fillings form veins whilst wall rocks are subjected to silicification.
4. Greisenization:	This stage is characterized by the origin of aluminosilicates (topaz, micas) with re-deposition of quartz. Ore mineralisation is related to the final periods of greisenisation.
5. Tourmalinization:	A simple mineralization stage characterized by the origin of tourmaline in veins and wall rocks, in places accompanied by ore mineralization.
6. Chloritization:	This is the main sulphide-bearing stage during which As, Fe and Zn sulphides are deposited.
7. Sericitization:	Widespread mineralization accompanies the deposition of simple sulphides of Cu, Pb and Zn, during this stage.
8. Argillization:	This stage is characterized by the origin of complex sulphides and sulphosalts with wall rock kaolinization or carbonate formation.

Relationships between pegmatites and quartz veins

The suggested classification is based on the observation that pegmatites and quartz ore veins are genetically different bodies (ŠTEMPROK 1965). Pegmatites do not pass transitionally into ore veins within a single mineralization stage. Thus, soon after their formation, the pegmatites may be affected by the later stages of feldspatization (albitization or potashfeldspar metasomatism) or greisenization.

Relationship between skarns and greisens

According to SOKOLOV and KOMAROV (1968) in those areas where skarns and greisens were formed during a single stage of magmatism, greisen mineralization followed the formation of the typical skarns (i.e. typical silicate skarn with magnetite). Greisen development subsequent to skarn formation differs for magnesian and calcareous skarns.

Tin, tungsten and molybdenum deposits

The sequence of stages involved in the formation of tungsten deposits is almost identical to those for tin deposits. Tin and tungsten ores therefore, may co-exist in many types of deposits. However, tungsten shows a possible association with gold in the tourmaline and chlorite stages of ore deposition whilst molibdenum is rarely associated with these stages.

Graphical representation

The main mineralization stages occur in a definite eightfold sequence but in most deposits only 2 or 3 stages are developed. The number of possible combinations —if the order of the stages is invariable from 1 to 8— can be expressed by a simple mathematical formula:

single stage: 8C1 = 8
two stages: 8C2 = 28
three stages: 8C3 = 56

In total there are 92 possible combinations of the 8 stages in groups of 1, 2 or 3. However, this number can be considerably reduced when it is considered that only 2 or 3 sequential stages are generally combined, and that 1 or 2 subsequent sequential stages may be absent. This results in about 53 possible combinations of which about 10 - 20 combinations of the stages commonly occur in nature.

Plutonic Sn, W and Mo ore deposits can be graphically represented by an octagon whose edges represent the eightfold stages in the development of mineralization. The bisectrix of each angle is drawn to the centre of the octagon to give a series of triangles, quadrangles or more complex figures whose edges characterise the most important mineralization stages present in a deposit.

Figure 1 shows the various sequential stages for the development of tin deposits. Figure 2 presents the similar sequences for tungsten deposits. Bi and Be may be associated with the greisen assemblages, gold is a typical accompanying element of many tourmaline-chlorite types. Unlike tin and tungsten deposits molybdenum deposits (fig. 3) rarely show a complete development of all stages. In the classification suggested by KHRUSHCHOV (1961) the chlorite or tourmaline stages of mineralization are of no economic importance.

The application this classification to the physicochemical phases of late magmatic and post magmatic processes is shown in fig. 4. Each phase covers several stages of mineralization. For example the term «pneumatolysis» does not characterize the mineral content of a deposit but only indicates its position within the sequence of mineralization stages.

The proposed classification can be compared to that for tin deposits by RADKEVICH (1968) who distinguished pegmatite, skarn, quartz-cassiterite, cassiterite-silicate-sulphide and cassiterite-sulphide stages of formation. These formations can result from the combination of two or three simple mineralization stages (fig. 5).

The graphical representation of some tin deposits in the Central European metallogenic province of Czechoslovakia is presented in fig. 6, and the shaded areas of the octagons show the main mineralization stages which gave rise to a particular deposit.

Terminology of the deposits

The names of deposits may be derived from the most important ore minerals (cassiterite, wolframite, scheelite, etc.) and from the main mineralization stages active in the formation of a deposit. Thus the cassiterite quartz veins with wall-rock greisenization may be termed as cassiterite quartz-greisen deposits, those with wolframite and quartz vein infilling and wall-rock chloritization as wolframite quartz-chloritic deposits. Examples are given in table I.

ACKNOWLEDGEMENT.—I thank Dr. PETER BOWDEN of the University of St. Andrews who commented the first version of the manuscript and offered many suggestions which helped to improve the text.

TABLE I

The names of some typical tin, tungsten and molybdenum deposits of plutonic geol. position

Tin, tungsten or molybdenum deposits — Stages	Symboles	Name of the deposit (cassiterite, scheelite, wolframite, molybdenite)
quartz-greisenization	3-4	quartz-greisen deposit
quartz-sericitization	3-7	quartz-sericitic
quartz-greisenization sericitización	3-4-7	quartz-greisen-sericitic
tourmalinization-chloritization	5-6	tourmaline-chloritic
skarnization silicate oxide stage	1 a, b	silicate-oxidic skarn
pegmatitization-feldspatization (albitization)	1-2	pegmatite-albititic
quartz-tourmalinization cloritization	3-5-6	quartz-tourmaline-chloritic
cloritization-sericitization	6-7	chlorite-sericitic deposit

REFERENCES

DENISENKO, V. K. (1975): *Classification of tungsten deposits for the purposes of their prognosis.* Zap. Vses. min. obshch., 104, vyp. 5, 526-538 (in Russian).

KHRUSHCHOV, N. A. (1961): *Molybdenum. The evaluation of deposit in the search and exploration.* Vyp. 19. Gosgeoltechizdat, Moskva (in Russian).

KRYLOVA, V. V. (1972): *The classification of tin-bearing deposits for the exploration purposes.* Geol. i razvedka, No. 3, 70-75 (in Russian).

LEVITSKII, O. D. (1947): *Genetic classification of tin-bearing deposits.* Geology of tin, Trudy inst. geol. nauk, vyp. 82, ser. rudnykh mestorozhdenii, No. 8. Izd. AN SSSR, Moskva-Leningrad (in Russian).

MATERIKOV, M. P. (1964): *Geological conditions in the appearence of the specialized tin-bearing intrusions. Metallogenic specialization of magmatic complexes.* Nedra, Moskva (in Russian).

RADKEVICH, E. A. (1968): *Tin-bearing formations and their practical significance.* Sov. geol., 1, 14-24 (in Russian).

SOKOLOV, G. A. & KOMAROV, D. V. (1968): *On the relationship between metalliferous greisens and skarns.* Rep. 23rd IGC, section 7, 305-312.

ŠTEMPROK, M. (1965): *On the transition of pegmatites into tin, tungsten and molybdenum-bearing veins.* Sbor. geol. věd, ser. LG, 7-38.

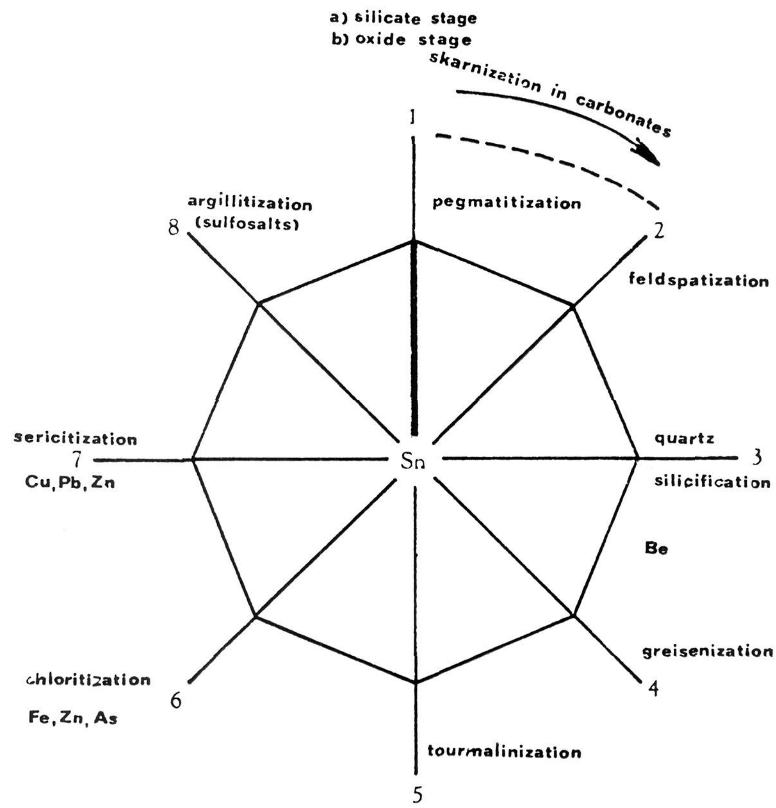

FIG. 1

Sequential stages for the development of endogenous tin deposits

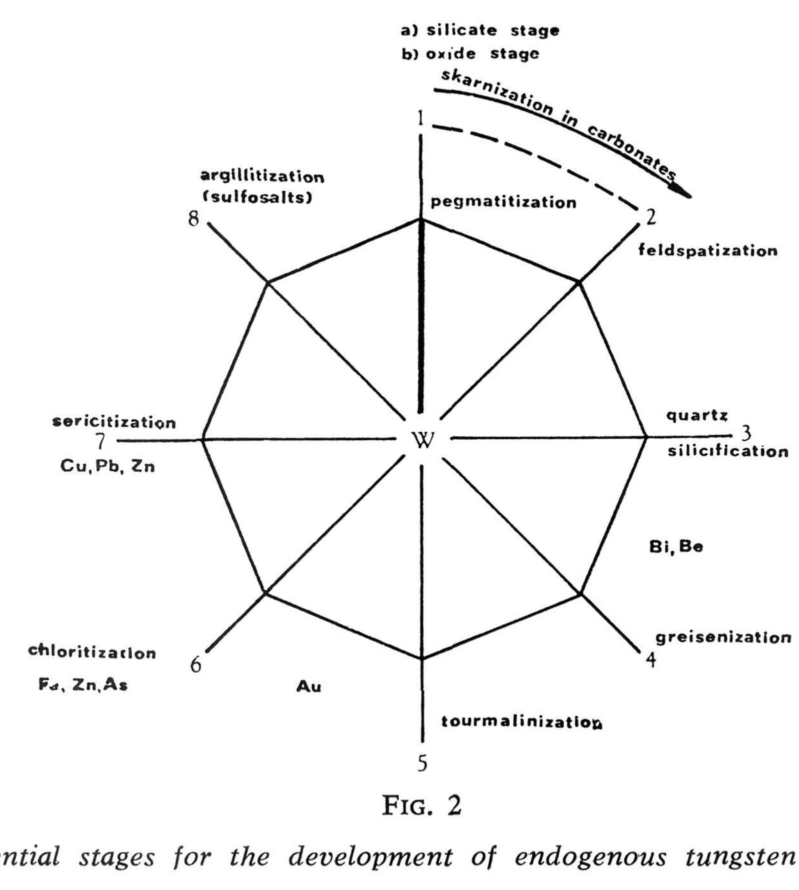

FIG. 2

Sequential stages for the development of endogenous tungsten deposits

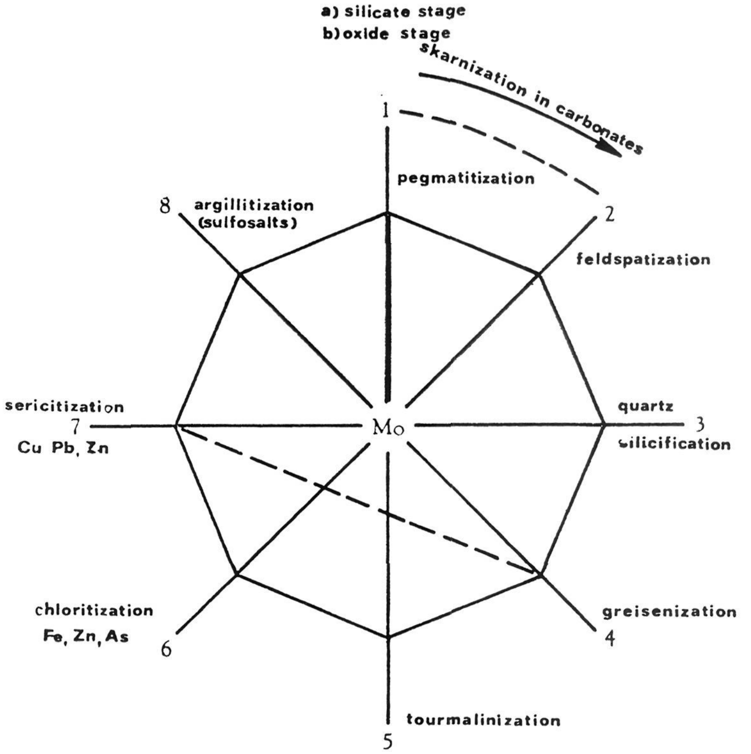

FIG. 3

Sequential stages for the development of endogenous molybdenum deposits. The chlorite and tourmaline stages are of little economic importance

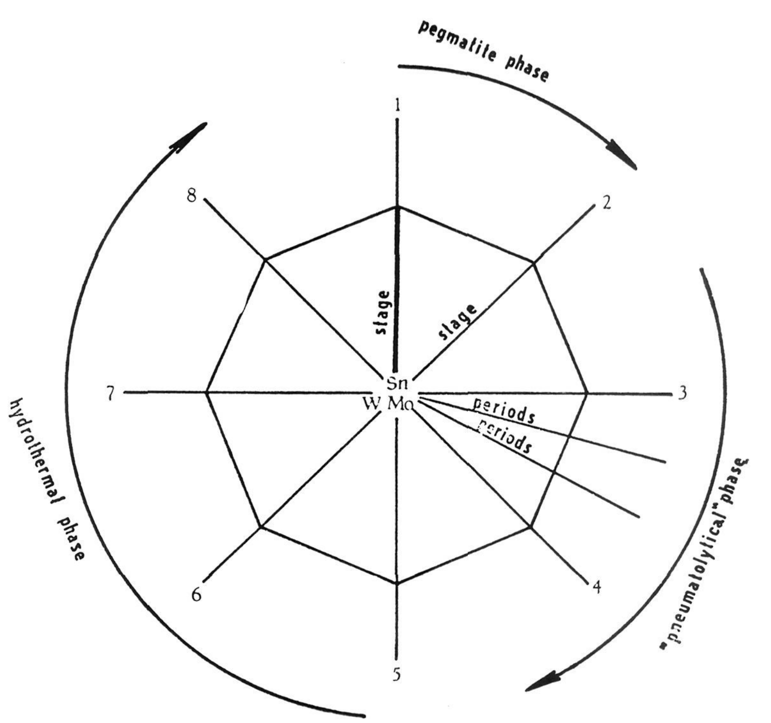

FIG. 4

Comparison of the proposed classification with the physico-chemical phases of late magmatic and postmagmatic processes

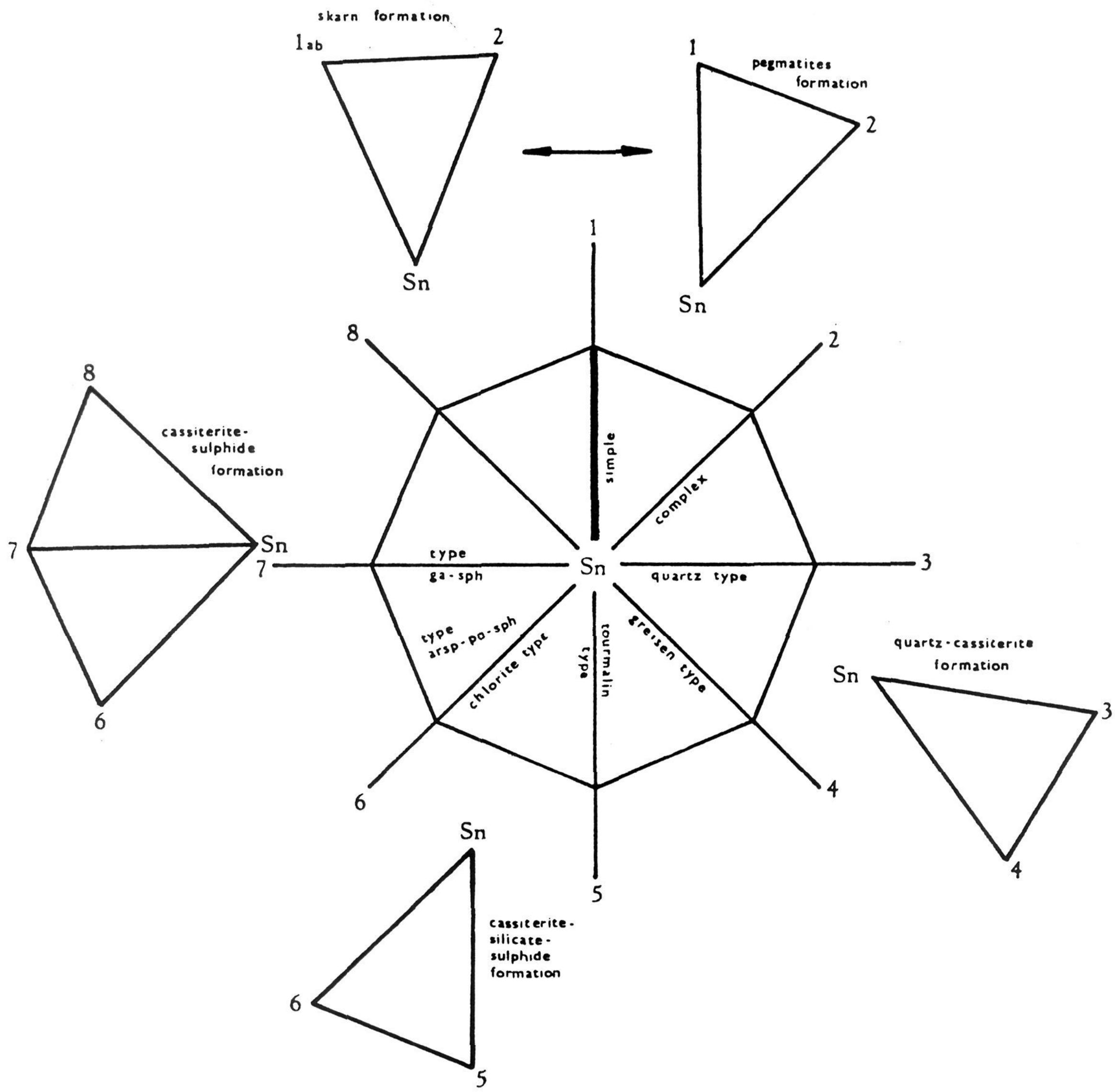

FIG. 5

Comparison of the proposed classification with the formational classification devised by Radkevich (1968)

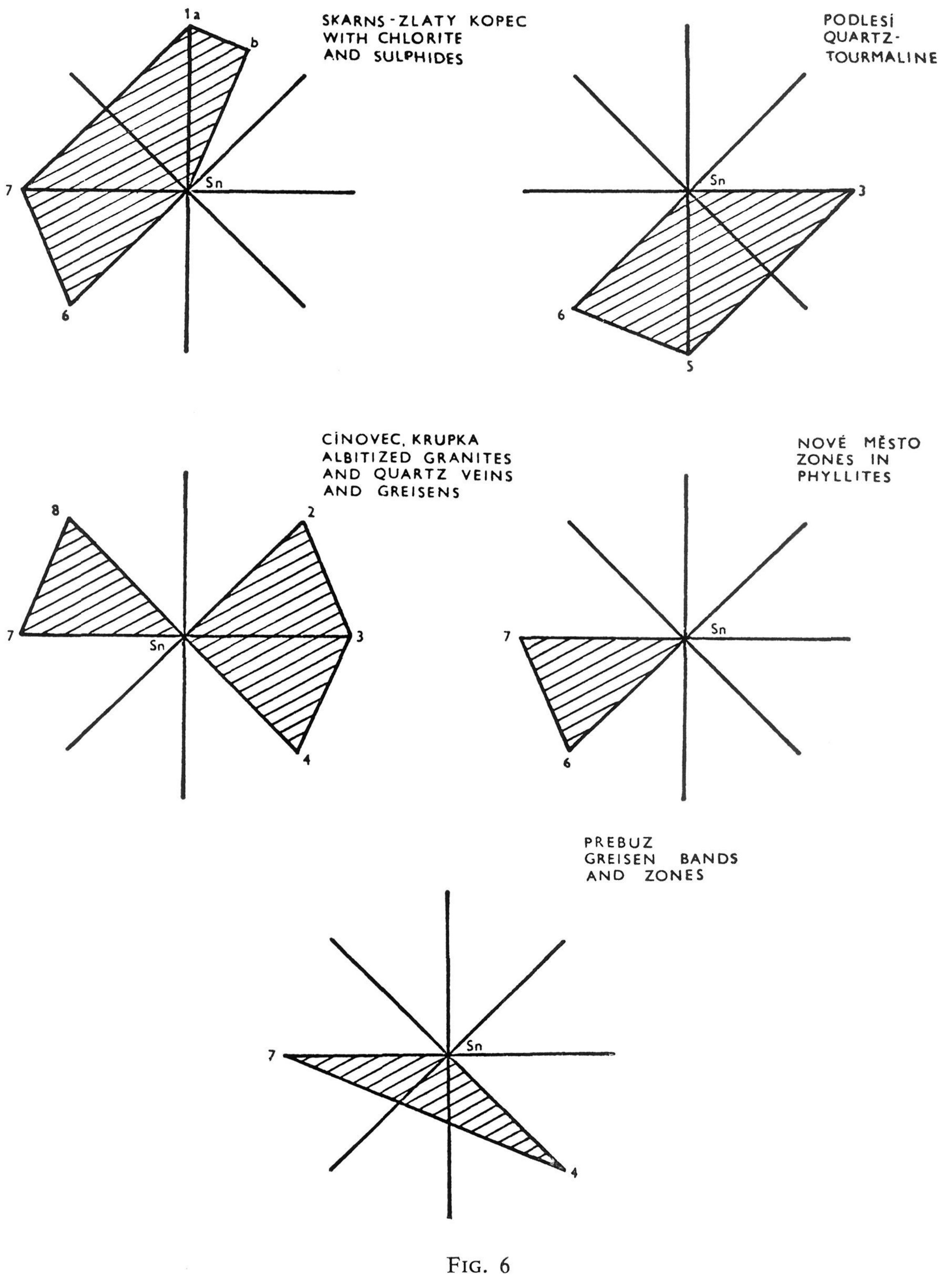

FIG. 6

Example of the application of the proposed classification to some deposits of the Central European metallogenic province of Czechoslovakia

a) *Skarn deposit Zlatý Kopec with silicate and oxidic skarn, superimposed chloritic and sericitic mineralization with sulphides.*
b) *Podlesí-quartz veins or tourmaline bands with weak chloritization.*
c) *Cínovec, Krupka-albitites, quartz veins with wall-rock greisenization.*
d) *Nové Město-chloritization zones with cassiterite impregnation accompanied by sericitization.*
e) *Přebuz-greisen zones without quartz accompanied by sericitization. Tourmalinization and chloritization is lacking.*