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# FORMATION OF SKARNS AND OTHER CALC-SILICATE ROCKS FROM THE SUDETES

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Abstract: The occurrence of the calc-alumo-silicate rocks in the Polish part of the Sudetes, southwestern Poland, is characterized. The rocks can be classified into two groups: skarns and erlans. Skarns, mostly of Ca type, are generally younger and composed of high-Fe silicates. They host relatively large volumes of Fe, As and/or polymetallic ores. The formation of skarns is related to the contact-metasomatic activity of Variscan granitoids or other silicate rocks. Erlans (skarnoids, rogoviks) are predominantly older and consist of low-Fe silicates and feldspars. Their origin is due to the transformation of calcareous-marly, partly clayey sediments during the regional metamorphism.

Key words: Erlans, skarns, Variscan granitoids, Sudetes.

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## INTRODUCTION

The authors review the most important localities of calcium-alumo--silicate rocks that occur in the Polish part of the Sudetes Mts., southwestern Poland.

The rocks differ in terms of mineral composition, structure and texture. Some are accompanied by ore mineralization. In many cases the relation to the igneous activity is obvious but some localities are distant from the known magmatic intrusions.

Considering the recent literature, skarn-like rocks can be classified into two groups:

- skarns;
- erlans, skarnoids, rogoviks.

Both types may occur independently or may be spatially and genetically related. In the latter case their relations indicate that the formation of erlans preceded that of skarns.

Skarns and erlans occur mainly in two sub-units of the Polish part of the Sudetes (Fig. 1): (I) Lądek-Śnieżnik metamorphic complex, (II) Karkonosze--Izera block.

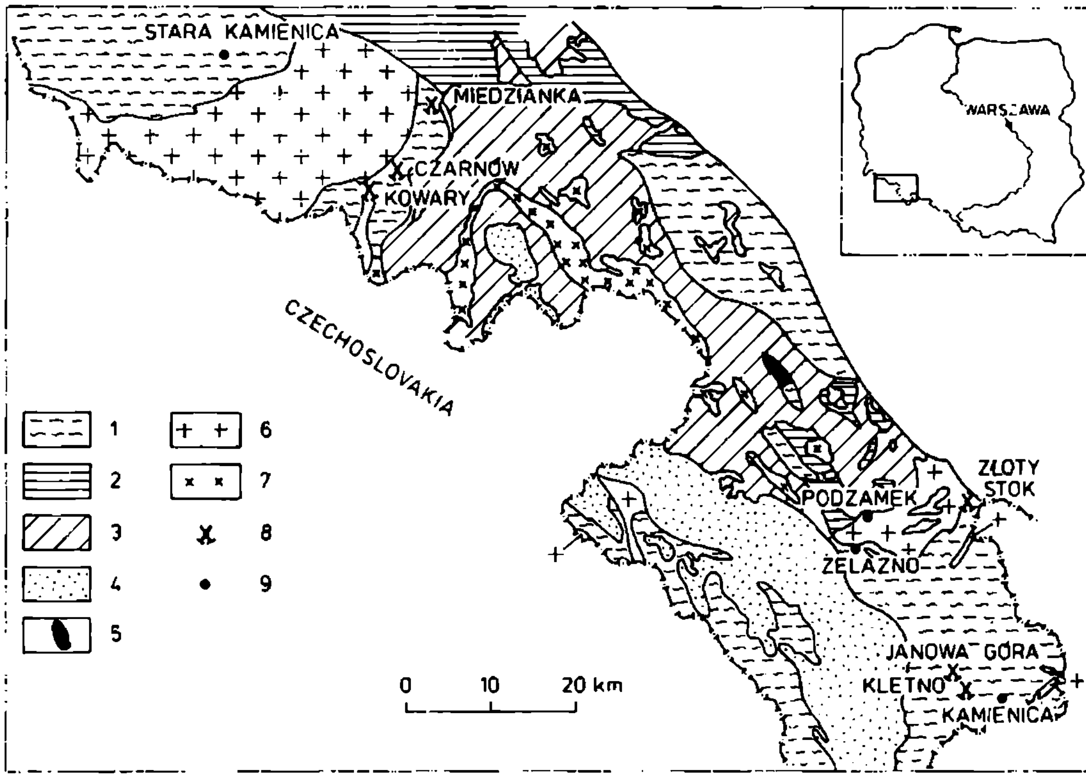


Fig. 1. Geological map of the Sudetes Mts., after Sawicki & Teisseyre (1979), simplified. *1*—metamorphic rocks, amphibolites and diabases of Precambrian and Palaeozoic age; *2*—*4*—unmetamorphozed or weakly metamorphozed sedimentary rocks: *2*—Eocambrian—Devonian, *3*—Carboniferous—Triassic, *4*—Upper Cretaceous; *5*—pre-Variscan gabbros; *6*—Variscan granitoids, *7*—Upper Carboniferous and Lower Permian volcanic rocks; *8*—abandoned mine;

The Lądek-Śnieżnik metamorphic complex embraces the Upper Proterozoic metamorphic rocks of suprainfracrustal succession. H. Teisseyre *et al.*, 1979). The Kłodzko-Złoty Stok granitoid intrusion involved in the formation of skarns is regarded as Variscan.

The Karkonosze-Izera block consists of two main components: Karkonosze granite intrusion of Variscan age and a metamorphic cover which, in the northern and eastern parts, is of Proterozoic (?) and Lower Palaeozoic age (J. Teisseyre, 1973; Smulikowski, 1972).

## SKARNS

Skarns occurring in the Sudetes can be divided in two types (*cf.* Einaudi *et al.*, 1984): Ca-skarns, Mg-skarns.

Ca-skarns were found in the metamorphic suits of Lądek-Śnieżnik complex (Kletno, Janowa Góra) and the metamorphic cover of the Karkonosze granite (Kowary) (Fig. 1).

In the Lądek-Śnieżnik metamorphic complex skarns were formed along the contact between marbles and granitic gneisses of Śnieżnik (Kletno, Janowa Góra) (Fig. 2; Pl. I: 1). They form lenses up to two metres thick (Banaś, 1965).

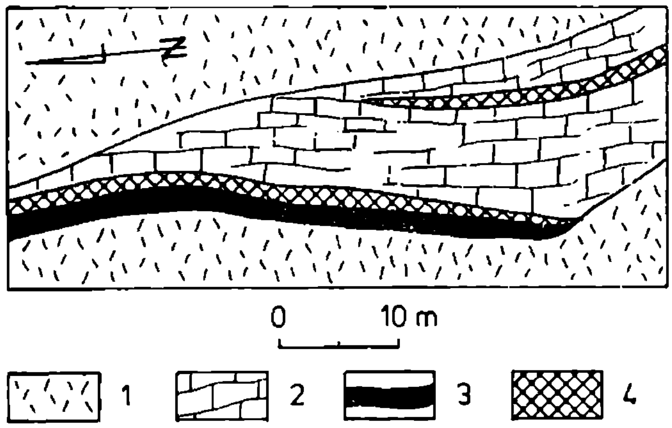


Fig. 2. Map showing occurrence of magnetite ore body, Janowa Góra mine. *1* – Śnieżnik gneiss; *2* – marble; *3* – magnetite ore; *4* – skarn

The rock is dark to black, medium- to coarse-crystalline with random structure. Magnetite accumulations are macroscopically visible. The mineral composition is dominated by garnets (grossularite, andradite), hornblende, pyroxenes (hedenbergite) and pistacite. Accessory minerals are: actinolite, biotite, muscovite, phlogopite, microcline and rarely orthoclase, plagioclases, quartz and cassiterite. The latter is paragenetically related to chlorite. Locally, high concentrations of ore minerals were observed: magnetite at various stages of martitization, high-Fe sphalerite (even anisotropic), martite, pyrite, chalcopyrite, arsenopyrite, pyrrhotite, cosalite and weathering minerals: covellite and Fe-oxides. In some parts of the skarn, veinlets and nests of calcite and fluorite are present. Monomineral skarns were also observed: hornblendic, hedenbergitic and/or andraditic. These varieties reveal granoporphyroblastic texture and random structure.

Accumulations of magnetite were found not only in the skarn but also in marble and schist and at the contact between schist and granitic gneiss. In such cases magnetite is devoid of sulphides.

In Kowary (eastern part of the metamorphic cover of Karkonosze granite) skarns were observed in the so-called „ore-bearing formation", in the vicinity of erlans, schists and marbles, rarely within the huge marble bodies. In one case only the contact of skarn with a granite apophysis has been observed. In the mine workings of the presently inactive Kowary mine, the so-called „skarn layers" have been exposed and are about 4 metres thick, located at least 18 m from the granite (Mochnacka, 1966). Skarn layers are concordant with the bedding of wall-rocks (Fig. 3). In detail, however, metasomatic contacts are common (Fig. 5; Pl. I: 2). Skarns from the Kowary mine are coarse- to medium-crystalline pink-green and dark in the vicinity of magnetite bodies. Bedding is absent. Main minerals are: garnets (andradite), pyroxenes (diopside), epidotes (clinozoisite, pistacite), hornblende. Locally vesuvianite is abundant. Accessory minerals are: calcite, feldspars, talc, prehnite, titanite and opaque minerals (Mochnacka, 1967).

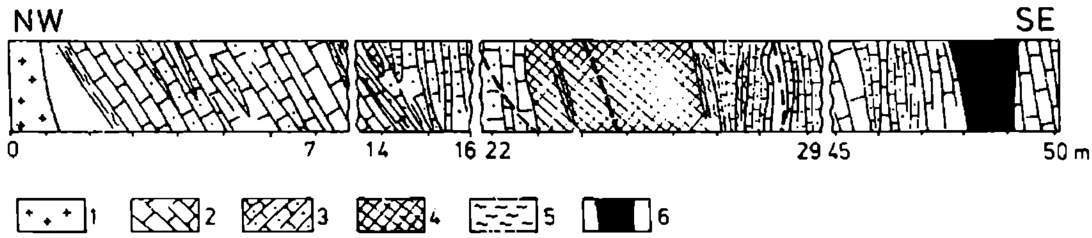


Fig. 3. Sequence of rocks in exposure in Kowary mine. *1* – Karkonosze granite; *2* – marble; *3* – erlan; *4* – skarn; *5* – crystalline schist; *6* – magnetite ore

The relationships between skarns and ore mineralization are not entirely understood. Pyrite and chalcopyrite are common, along with pyrrhotite (Mochnacka, 1967). Skarns usually accompany magnetite deposits (Fig. 4) but barren skarns were also observed along with magnetite bodies located within

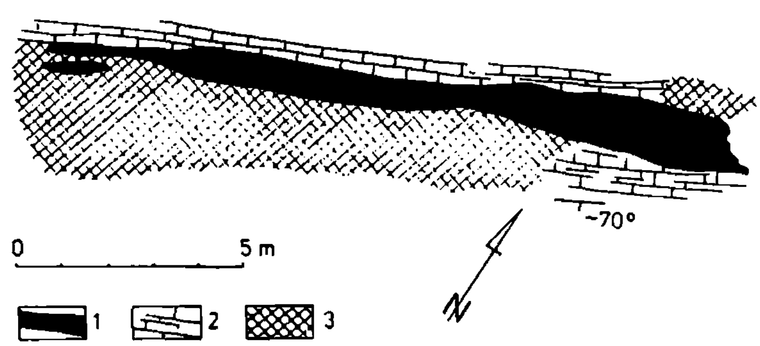


Fig. 4. Map of magnetite ore body, Kowary mine. *1* – magnetite ore; *2* – marble; *3* – skarn

other host-rocks (Fig. 3). According to Zimnoch (1961) skarn-related magnetite bodies form one of the three types of magnetite occurrences in the Kowary deposit.

Other small occurrences of calcite-silicate rocks and silicate rocks formed as a result of contact matamorphism were found in an aureole of Kłodzko-Złoty Stok granitoids. They were described for example in Podzamek, Żelazno and other places (Juskowiak, 1959; Wierzchołowski, 1976). At Miedzianka (Fig. 1) a polymetallic deposit contains magnetite of contact-metasomatic origin that was generated by the replacement of calcium-silicate minerals (Krusch, 1901 *fide* Zimnoch, 1978). Some studies (Berg, 1913) had revealed the presence of diopside and diopside-garnet rocks in which intercalations enriched in ilvaite were present.

Mg-skarns have been described by Kowalski (1967) from Złoty Stok at the contact zone between dolomitic marbles and schists. The rock is composed mainly of diopside and tremolite with phlogopite, chondrodite and accessory minerals: talc, prehnite, garnets, quartz, chlorite, hornblende, actinolite, biotite, albite, oligoclase, orthoclase and anatase. Microscopic studies allowed for distinguishing of some Mg-skarn varieties: diopsidic, diopside-tremolitic and monomineral tremolitic (the so-called Złoty Stok nephrites). Serpentinization processes are well marked. Skarns from Złoty Stok are mineralized. Loellingite ores form the oldest generation and are succeeded by sulphide assemblages.

## GENETIC REMARKS

The skarns described above resulted from metasomatic processes developed by various geological conditions. Skarns from Kletno were presumably formed during regional metamorphism by the transformation of iron-rich, clay--calcereous sediments. The Śnieżnik gneisses (palingenetic?) were the source of poorly-marked metasomatosis that resulted in a superimposed zonality (hedenbergite, andradite and hornblende stages). During these processes the second metasomatic generation of magnetite was formed. The origin of sulphide assemblages is ascribed to the metasomatic activity of Śnieżnik magma, as well.

Skarns from Kowary resulted from the metasomatosis of marbles, schists and earlier-formed erlans. Variscan granite of the Karkonosze Mts. was a source of the contact-metasomatic processes. In the early stage these processes generated the post-kinematic amphiboles (hornblende-hornfels facies, after Turner & Verhoogen, 1960). Subsequently, transfer of substances took place, presumably accompanied by the ion exchange between silicater rocks (erlans and schists) and marbles. Altered zones were enriched in Mg, Fe, Si and Al. According to Zimnoch (1961) the source of iron were ferruginous sediments transformed during regional metamorphic processes.

Ore deposits at Kowary constitute the well-known hydrothermal, polymetallic-uranium locality. Uranium-bearing veins penetrated into skarns which proves their post-skarn origin.

Mg-skarns are the effect of metasomatosis genetically related to the intrusion of Kłodzko-Złoty Stok granitoids. Dolomitic marbles along with diopside-oligoclase-hornblende-biotite skarnoids were transformed into skarns (Kowalski, 1967). The metamorphic complex was formed in amphibolite facies, whereas skarns are the products of the greenschists one. According to Kowalski (1967), ore mineralization in Złoty Stok is clearly connected with the Variscan Kłodzko-Złoty Stok intrusion.

## ERLANS (SKARNOIDS, ROGOVIKS)

Erlans are usually developed along the contacts between schists (paragneisses) and marbles or dolomitic marbles. They usually form an aureole several centimetres to several metres thick. Layering or lamination are common features.

Erlans reveal generally bright colours (greenish, greenish-grey), rarely dark, resulting from the arrangement of rock-forming minerals. Rock structure is usually ordered with the preserved primary bedding (Pl. I: 3). Texture may grade from fine-crystalline to aphanitic. Usually, veinlets of quartz, calcite and feldspars are visible.

The best developed section of skarnoids may be observed in the mine workings of the presently inactive Kletno mine (Banaś, 1963). Skarnoids are located at the contacts of marbles and biotitic paragneisses (Fig. 5). The

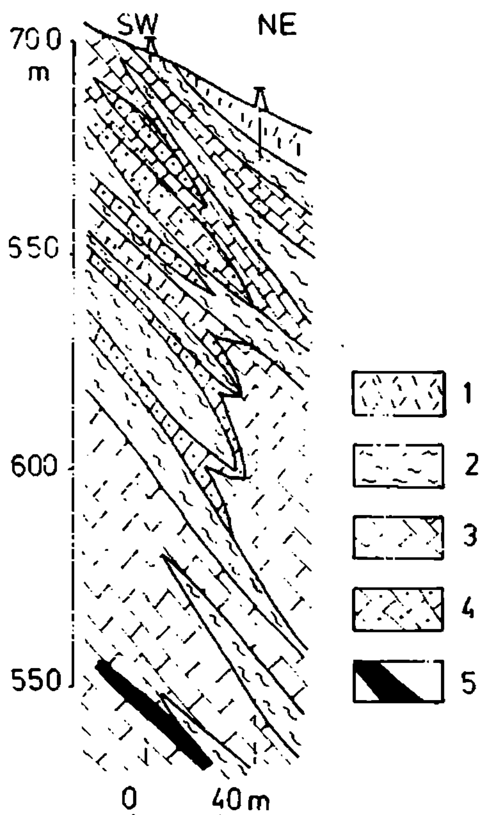


Fig. 5. Geological section through NW part of Kletno ore deposit. *1* – Śnieżnik gneiss; *2* – crystalline schists and biotite paragneiss; *3* – marble; *4* – skarnoid; *5* – magnetite ore

marbles are thick-bedded, white or slightly coloured. Spotty or streaky accumulations of silicates are visible within calcite granoblasts. They include micas, chlorite, amphiboles, pyroxenes, garnets, epidote and phlogopite. The appearance of silicates gives green colouring to the rock. Simultaneously, the bedding disappears and cataclasis is a common feature along with fine--crystalline texture. Biotitic paragneisses are dark, well bedded and sporadically contain small amounts of silicates typical of skarnoids.

Two types of skarnoids can be distinguished in the Kletno deposit:

(1) pale green, low-Fe, composed of salite, zoisite-clinozoisite, tremolite, grossularite and plagioclase. This type is typical of the contact with carbonate rocks;

(2) dark (deeper green) consisting of ferrosalite, epidote, biotite, chlorite, hornblende and K-feldspars (orthoclase-microcline). Larger amounts of titanite, pyrite, chalcopyrite and pyrrhotite were found along with spectrographically detected traces of tin.

Microscopic studies of the samples from the Kletno deposit provided a more detailed classification of skarnoids. There occur here:

– epidote-clinozoisite type with high content of andesine or salite,

– feldspar type containing microcline and orthoclase porphyroblasts in the zones adjacent to gneisses or andesine ones close to marbles,

– pyroxene type with dominating salite-ferrosalite and calcite,

– garnet-quartz type in which xenoblastic quartz-calcite assemblage is intergrown with numerous porphyroblastic grossularite and hydrogrossular,

– termolite type.

Basing on microscopic studies of erlans derived from the outcrops in the vicinity of Kamienica Valley and waste dumps of Kletno and Janowa Góra mines (Fig. 1 – all the localities are located in the SE part of the Lądek-Śnieżnik metamorphic complex), J. Teisseyre (1959) distinguished three types of erlans:

– epidote type with diopside,

– hornblende type,

– transitional rocks between erlans and marbles: vesuvianite erlans, phlogopite marbles, actinolite marbles and epidote marbles.

In the Złoty Stok deposit (Fig. 1), Kowalski (1967) described as skarnoids the rocks from the contact zone between dolomitic marbles (19–20% MgO) and oligoclase-biotite schists. Skarnoids occur in the vicinity of Mg-skarns. The rocks are composed of diopside and tremolite and reveal granoblastic textures and oriented structures.

In the Karkonosze-Izera block, calcium-silicate rocks were mapped in several localities. The best examples were derived from the Kowary magnetite deposit (Fig. 1). The general characteristic of erlans from Kowary corresponds to the analogous rocks from Kletno deposit (Fig. 3). Microscopic studies allowed for distinguishing their four varieties (Mochnacka, 1967):

– salite-feldspar,

– feldspar-tremolite,

– feldspar-salite-amphibole,

– salite-garnet or feldspar-biotite-amphibole.

The accessory minerals contained in all varieties are: phlogopite, titanite, zoisite, clinozoisite and scapolite.

In the same deposit, Zimnoch (1961) identified seven types of rogoviks: diopside, diopside-garnet, diopside-plagioclase, diopside-hornblende, epidote, hornblende-epidote, hornblende-plagioclase.

Skarnoids are known also to occur in the neighbourhood of Kowary. J. Teisseyre (1973) described garnet-pyroxene erlans from the area of Miedzianka. After Berg (1913) the continuation of the same calcium-silicate rocks occurs in the As deposit at Czarnów (Fig. 1).

In the northern part of the metamorphic cover of the Karkonosze granite, Kozłowski (1974) described epidote erlans from Stara Kamienica (Fig. 1). These rocks are composed of epidote, clinozoisite, garnet and sporadically, vesuvianite. Szałamacha (1965) distinguished biotite and zoisite erlans with finely crystalline texture and random structure. The erlans are located in gneiss-schist series, in the vicinity of leucocratized Izera gneisses.

### GENETIC REMARKS

Most of the authors describing erlan (skarnoid, rogovik) occurrences agree that these rocks resulted from isochemical regional metamorphism of marly-calcareous, partly clayey sediments. This process operated in an environment corresponding to the amphibole, epidote-amphibole (Williams *et al.*, 1957) or amphibole-almandine (Turner & Verhoogen, 1960) metamorphic facies. According to Ramberg (1952) the highest temperature of formation of skarnoids does not exceed 500°C.

Some observations suggest that crystallization continued during the subsequent metasomatosis related either to the thermal activity of the Karkonosze granite or to the paragneisses and schists in other regions. Hydrothermal solutions mobilized in such conditions invaded the carbonate rocks introducing the new ions: Si, Fe, K, Na, S, and partly Al and Mg. Some of these elements could be in part the redeposited components of metamorphosed rocks. The effects of the suggested metasomatic events are apparent in the presence of marble relics embedded in skarnoids (Pl. I: 4). Well-marked is the zonal distribution of erlan silicates especially plagioclases and K-feldspars which locally form large idioblasts. Thermal metamorphism is documented also by the post-kinematic character of the amphiboles (hornblende, tremolite).

## CONCLUSIONS

Studies of the skarn-type rocks from the Sudetes provide for the recognition of some regularities governing their fromation and distribution.

The skarns originated from metasomatic processes. The source of metasomatizing solutions were Variscan granitoid intrusions or other silicate rocks.

Commonly, accumulations of iron (magnetite), arsenic (loellingite, arsenopyrite) and sulphide ores are hosted within the skarns. The skarn-forming processes influence the wall-rocks and cause significant changes. In detail, they may:

– generate the ore minerals (e.g., contact metasomatic deposit in Miedzianka),

– superimpose upon and modify the pre-existing ore accumulations (e.g. Kowary, Kletno, Janowa Góra deposits),

– host the ore mineralization (e.g. polymetallic ores from Złoty Stok, Kowary, Kletno).

Erlans-skarnoids-rogoviks were formed during regional metamorphism, as a result of the transformations of marly, calcareous-marly and/or, partly, clayey sediments. They occur as transition zones at the contacts of schists (paragneisses) and marbles. Typically they exhibit oriented and/or laminated structures inherited after the primary, sedimentary rocks.

The formation of erlans is connected with isochemical recrystallization processes, whereas the origin of skarns resulted from thermal-contact processes operating over a wide range of temperature and with a considerable influence of the chemical components by diffusion and infiltration.

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## Streszczenie

# SKARNY I SKAŁY SKARNOPODOBNE W SUDETACH

**Marian Banaś & Ksenia Mochnacka**

Skarny i skały skarnopodobne w Sudetach można zakwalifikować do dwóch grup: (1) skarny, (2) erlany (skarnoidy, rogowiki). Te grupy skał występują bądź niezależnie, bądź wykazują przestrzenny i genetyczny związek. Są one znane głównie z obszaru metamorficznej osłony granitu Karkonoszy i z obszaru metamorfiku Lądka i Śnieżnika (Fig. 1). Nawiązując do klasyfikacji Einaudiego *et al.* (1984) skarny można z kolei podzielić na skarny wapniowe i skarny magnezowe. Pierwsze z nich opisane zostały z okolic Kletna, Janowej Góry i Kowar (Fig. 2–4, Pl. I: 1, 2); inne drobne ich wystąpienia stwierdzono w aureoli kontaktowej masywu Kłodzko-złotostockiego (Podzamek, Żelazno i in.). Skarny magnezowe znane są ze Złotego Stoku. Erlany występują w okolicy Kletna, Janowej Góry (metamorfikum Lądka i Śnieżnika), a także w osłonie granitu Karkonoszy (Kowary, Miedzianka, Czarnów, Stara Kamienica).

Skarny powstały w wyniku procesów metasomatycznych, a źródłem roztworów były granitoidy waryscyjskie lub inne skały krzemianowe. Procesy skarnotwórcze doprowadziły do: (1) utworzenia zespołów minerałów kruszcowych w rezultacie metamorfizmu kontaktowego (Miedzianka), (2) przekształcenia istniejących wcześniej złóż (Kowary, Janowa Góra), (3) depozycji rud polimetalicznych (Złoty Stok, Kletno, Kowary).

Erlany (skarnoidy, rogowiki) powstały w procesach metamorfizmu regionalnego, w wyniku przekształcenia marglistych, wapienno-marglistych oraz ilastych (w części) osadów. W typowym wykształceniu wykazują one laminację odziedziczoną po skałach osadowych. Powstawanie erlanów związane było z izochemicznymi procesami krystalizacji, skarny natomiast tworzyły się w wyniku procesów kontaktowych, przebiegających w szerokim zakresie temperatury, przy znacznej wymianie składników chemicznych drogą dyfuzji i infiltracji.

## EXPLANATION OF PLATE

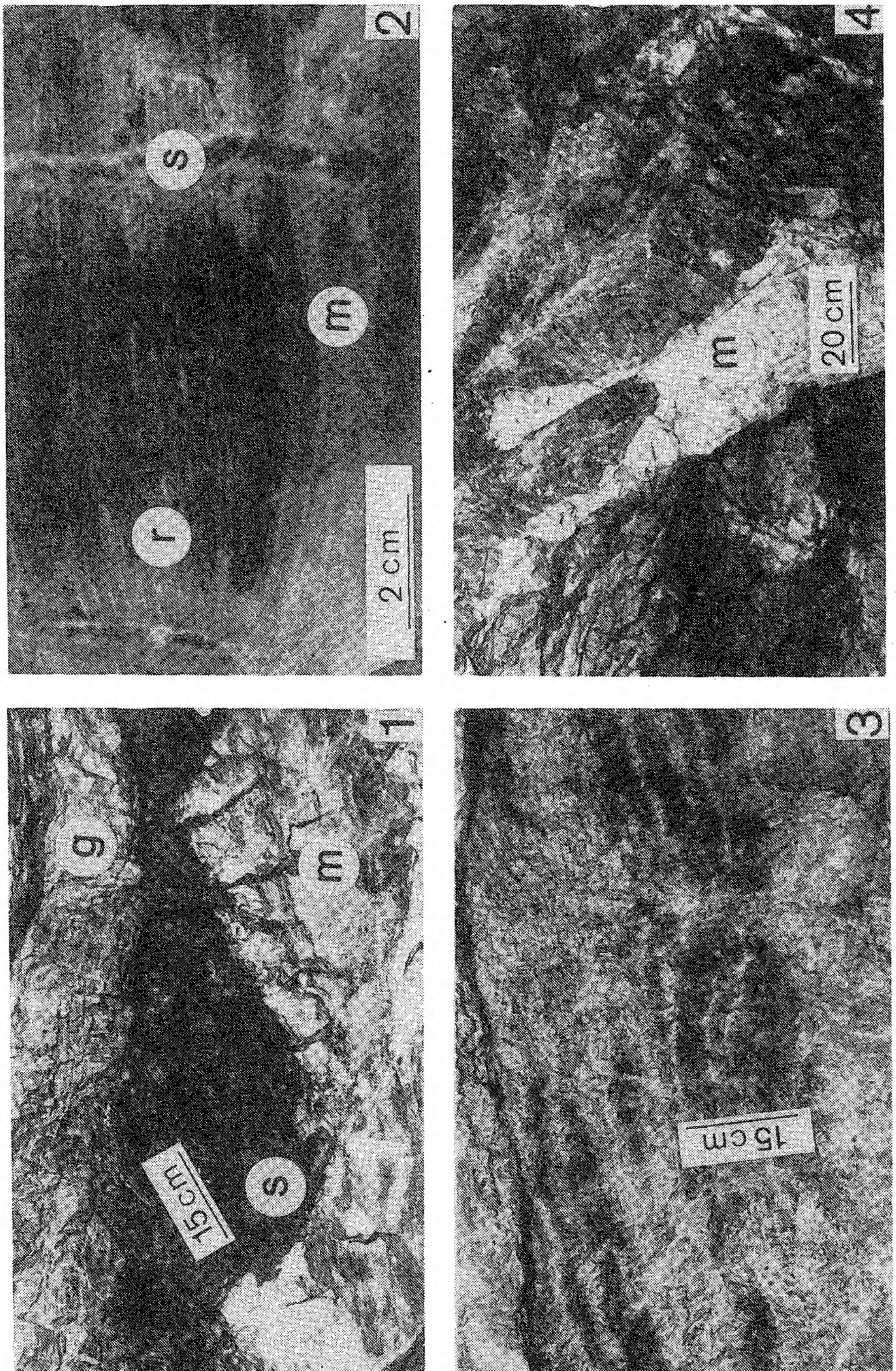
### Plate I

1 — Amphibole-pyroxene-garnet magnetite-bearing skarn (*s*) between Śnieżnik gneiss (*g*) and marble (*m*). Kletno mine

2 — Polished section of rock intermediate between erlan-schist (*r*) and marble (*m*). The fissure is filled with typical skarn (*s*). Along the fissure the metasomatic replacement of both rocks is visible; initial stage of metasomatosis. Kowary mine

3 — Laminated skarnoid near the contact with biotite paragneiss, as a product of the transformation of original sediment. Dark bands are composed of microcline, ferrosalite and biotite, light bands of grossularite, quartz and plagioclase. Kletno mine

4 — Unaltered relict of marble (*m*) oriented transversally to the stratification of surrounding skarnoid. Kletno mine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