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COLLAPSE BRECCIAS IN THE ORE-BEARING DOLOMITE OF THE OLKUSZ MINE (CRACOW-SILESIAN ORE-DISTRICT)

(5. Figs.)

Brekcje zawałowe w dolomitach kruszconośnych kopalni Olkusz (rejon śląsko-krakowski)

(5 fig.)

Abstract: This study was undertaken to describe and interpret the breccias that host the zinc-lead ores in the Olkusz mine (Cracow—Silesian ore-district). The breccias represent typical collapse structures consequent upon the removal of support by the dissolving action of solutions and were formed in already lithified dolomites.

INTRODUCTION

The Olkusz zinc and lead mine belongs to the Cracow-Silesian ore district and is located about 30 km north-west of Cracow. Like most of the Zn-Pb deposits in the Cracow-Silesian district the Olkusz ores occur in the Triassic carbonate rocks. These rocks, together with the Jurassic and Permian deposits, represent a post-hercynian platform cover and rest almost horizontally upon the folded Paleozoic rocks. In the region of Olkusz the Paleozoic rocks range in age from Cambrian to Carboniferous (see e.g. Gruszczyk et al. 1968).

From evidence obtainable in the Olkusz mine it appears that the sulfide ores are closely associated with a specific type of breccias in the ore-bearing dolomite. Such breccias are the host for all economically important deposits. However, the mineralization is not uniform, the breccias are not always mineralized and certain parts of the breccia bodies may

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be notably devoid of sulfides. Therefore the limits of the ore bodies do not necessarily correspond to those of the breccias. Such incongruency permits to discuss in separate fashion the origin of breccias and the genesis of ores, although both problems are mutualy related. The following considerations are limited to the origin of the breccia structures. The second question, namely the genesis of sulfide ores resident in breccias will be dealt with in a forthcoming publication.

The breccias under consideration have been repeatedly discussed and variously interpreted. They were regarded as tectonic breccias by K. S e i d l (1927), as resulting from dolomitization by F. W e r n i c k e (1931) and as produced by diagenetic processes by G ü r i c h (1903) and S e i d l (1927). Another explanation was that the breccias resulted from differences in the rate of diagenetic alterations between the alleged colloidal sulfide sediment and the intervening dolomitic layers (G r u- s z c z y k, 1956; S m o l a r s k a, 1968). Finally, the breccias were also attributed to karstic processes (A l t h a n s, 1891). S m o l a r s k a (1968) suggested that at least a part of the breccias described by her resulted from karstic processes operating in the zone of weathering and cementation (see also S m o l a r s k a, 1968). B o g a c z et al. (1970) explained the origin of ore-cemented breccias in terms of hydrothermal karst processes. In this interpretation the breccias were attributed to collapse of caves produced by hot mineralizing solutions. The existing literature, however, gives no detailed descriptions of the breccias. The aim of this article is to submit such descriptions and to present some new data that may help to resolve the argument around the origin of the breccias. Some of the problems discussed here were already dealt with in an earlier publication (see S a s s - G u s t k i e w i c z, 1970).

GEOLOGIC ENVIRONMENT

The breccias discussed here, like most of the zinc and lead deposits in the Cracow-Silesian region, are confined to the ore-bearing dolomite. The stratigraphic position and relationship of this dolomite to the surrounding Triassic rocks, have been discussed by several authors (i.e. S i e d l e c k i, 1948; Ś l i w i ń s k i, 1969). The sequence of geologic events leading to the formation of the ore-bearing dolomite and the ores has been briefly summarized by B o g a c z et al. (1970) and the reader is referred to their publication. At this place, however, it is necessary to mention that the ore-bearing dolomite exposed in the Olkusz mine corresponds to the Lower Muschelkalk (the Gogolin, Górażdże, Terebratula and Karchowice beds) and to the lower part of the Middle Muschelkalk (the Diplopora dolomite).

From observation of mine workings it appears that the breccias are

preferentially developed at the base of the ore-bearing dolomite, i.e. along the contact between the dolomite and the underlying limestones. The contact-surface is variously shaped. One can observe here irregular dolomitic bodies cutting across sedimentary structures. It is also common to find here limestone relics enclosed in the dolomite. The boundary between the dolomite and limestones may be horizontal through a distance of several tens of meters. In places, it may coincide with bedding planes. If this is the case, there is usually a few milimeters thick clayey layer between the ore-bearing dolomite and the limestone. Elsewhere, the contact surface, although roughly horizontal, shows wavy irregularities (up to 1,5 m in vertical extension) and cross-cutting relations to the sedimentary structures preserved in limestones (see M. S a s s - G u s t k i e w i c z 1971b). In general, the contacts of the ore-bearing dolomite in the Olkusz mine are very similar to those described by K. B o g a c z et al. (1972) from the Trzebionka mine, and point to a secondary origin of this rock.

The breccias are made exclusively of angular fragments of the dolomite. The limestone blocks may occur at the base of the breccia bodies. Such blocks are covered with a calcareous flour and invariably show somewhat oval shapes. The origin of such blocks is different from that of the angular dolomitic fragments. It is suggested that the oval-shaped limestone blocks did not result from crushing or fragmentation but represent the relics of undissolved calcarenites.

BRECCIA STRUCTURES

The term "breccia structure" is used here in its widest sense to indicate; 1) the breccia proper in which the rock fragments have been rotated and displaced, and 2) the "crackle" breccia in which the rock fragments are separated along transverse fractures and bedding planes without rotation of the blocks (compare H o a g l a n d et al., 1965).

To evaluate the genesis of the breccias discussed it is necessary to establish their size and shape. A determination of these features depends upon the quality of exposures. Owing to a network of mine workings, the Olkusz deposits are relatively well exposed. The workings attain 8 m. in height and are frequently superimposed upon each other. This gives an insight into the size and shape of the breccia structures.

The size of breccia structures

From direct observations it appears that the horizontal extension of the breccia structures varies from 150 to 300 m. The vertical extent of such structures is highly variable and may attain 30—50 m.

Horizontal sections

Because of limitations imposed by mine workings it is impossible to observe directly the shape of horizontal sections of large breccia structures. An aproximate outline of the breccia structures may, however, be obtained by interpolation of exposures. Fig. 1 shows two examples of
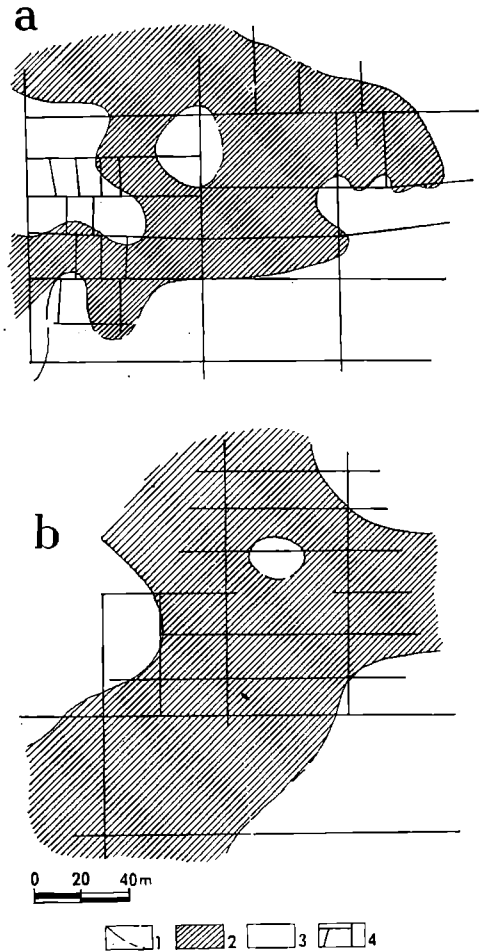

Fig. 1. Horizontal sections of breccia structures. 1 — boundaries of breccias; 2 — breccias; 3 — unbrecciated country rock; 4 — mine workings. Further explanations in text

Fig. 1. Przekroje poziome struktur brekcjowych. 1 — granica brekcji; 2 — brekcja; 3 — skały nie zbrekcjowane; 4 — wyrobiska górnicze. Dalsze wyjaśnienia w tekście

such interpolated sections. These examples are from two different breccia structures and represent two different levels. The section "a" is near the base of the breccia structure, while "b" is situated about 15—20 m above the base. The section „a" differs slightly from "b" in that the boundaries of the breccia structure are more irregular and complicated. This is due to the fact that the lower surfaces of the breccia structures are usually highly irregular solution surfaces showing a typical karst topography (see also below p. 223). The irregularity of the breccia section reflects the irregularity of such karst surfaces. Attention should also be directed to

the relics of unbrecciated dolomite surrounded by the breccia. Such relics represent irregular columns and pillars shown in fig. 2.

The irregular, non-linear outlines of the breccia structures as seen in horizontal cross-sections effectively eliminate the tectonic origin of the breccias.

Vertical cross-sections

Like it is the case of horizontal sections, the size of exposure does not permit to draw precisely the outline of vertical sections of large breccia structures. This, however, can be done by reconstruction. The procedure taken in such reconstruction is as follows: Each of the breccia structures may be divided, admittedly in a somewhat arbitrary fashion, into three zones: A, B and C which correspond succesively to the upper, middle and lower parts of the breccia structures. These zones differ in their relationship to the enclosing undisturbed host rock. Thus the upper zone ''A'' is bounded from above, ''B'' — from the sides and ''C'' — from below by the undisturbed country rock. The mine workings transect the various breccia structures at different levels providing thus a profusion of partial cross-sections that correspond to one or another of the distinguished zones.

In analyzing such partial sections one can observe that each of the distinguished zones of the breccia structures is characterized by certain specific and diagnostic features. Such features are repeated again and again at suitable levels in different breccias. Consequently, the partial sections corresponding to one or another zone of different breccias are strikingly similar. It appears thus legitimate to select the representative partial sections showing easily recognizable diagnostic features and project these sections into one model section (see fig. 5).

Before discussing the reconstructed model section it is necessary to submit some essential details pertaining to each of the distinguished zones within the breccia structures. Such details are illustrated below in some selected partial sections.

Z o n e A. The upper zone ''A'' occurs entirely within the ore-bearing dolomite. The partial section shown in fig. 2 illustrates the salient features of this zone. The undisturbed part of the section consists of four layers indicated by numbers 1—4. Each of the layers shows certain diagnostic features by which the fragments of layers may easily be identified within the breccia body. It is thus possible to trace the location of the detached fragments and to estimate the amount of displacement and rotation.

In analyzing the partial section along its horizontal extension the following segments may be differentiated:

S e g m e n t I. The dolomite flanking the breccia body from the side is

undisturbed, and the dolomite layers rest almost horizontally. Yet already here one can observe the incipient separation of layers along bedding surfaces, whereby the amount of such separation is greater in the lower part of the section than in the upper one. The separation increases also towards the center of the partial section discussed, i.e. towards the brecciated rocks. The increase in separation is accompanied by the appearance of transverse and vertical fractures the density of which increases towards the breccia body. The fractures are also more aboundant in the lower part of the segment that in the upper one.

S e g m e n t II. Although the dolomite layers are approximately still in their primary position they become increasingly separated along bedding planes and fractures. Towards the center of the section, the detached parts of the layers become increasingly displaced and the fractured dolomite passes gradually into a jumbled mass of sharply angular rock fragments. Here again the detachement of layers is more advanced in the lower part of the segment than in the upper part. This indicates that the breccia making proceded successively upwards, affecting first the lower layers and than the upper ones.

The gradual passage of crackle breccias into a chaotic aggregate of rock fragments clearly points that the breccias proper originated by detaching of crackle breccias.

S e g m e n t III. In this part of the section the brecciation is most advanced although the vertical displacement of fragments does not exceed 1 m. The size of sharply angular fragments varies from large slabs (up to 1,5 m in length) to small particles only a few milimetres in size. The arrangement of fragments is entirely random and the smaller fragments tend to fill the space between the large ones. The density of the interfragmental filling is, however, variable, and in places empty voids may occur.

S e g m e n t IV. This segment represents a columnar relic of undisturbed dolomite and the layers 1—4 occupy exactly the same position as in segment I. From both sides the relic is surrounded by angular breccias. The relationship between the undisturbed dolomite and breccia is very similar to that previously discussed.

S e g m e n t V is again a jumbled mass of unsorted angular fragments of the ore-bearing dolomite.

S e g m e n t VI. Here again the dolomite layers are undisturbed and at the same level as their counterparts in the segment I and IV. Also the relations between the undisturbed and brecciated parts of the dolomite are similar to those previously described.

Z o n e B. Fig. 3 shows a partial section that is representative for the middle parts of the breccia body. The section is entirely within the ore-bearing dolomite and its undisturbed portions consist of 7 layers differing in thickness. The section may be divided into 3 segments. The seg-
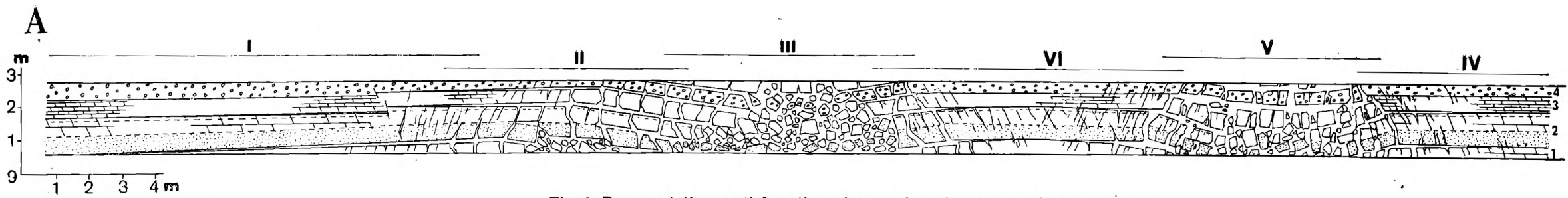
Fig. 2. Representative partial section of upper breccia zone. Explanation in text
Fig. 2. Przekrój częściowy charakterystyczny dla górnej części struktury brekcjowej. Wyjaśnienia w tekście
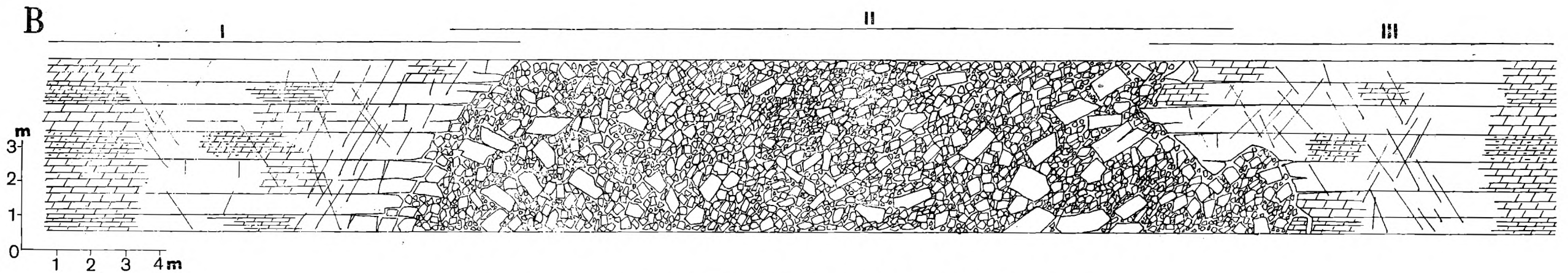

Fig. 3. Representative partial section of middle breccia zone. Explanation in text
Fig. 3. Przekrój częściowy charakterystyczny dla środkowej części struktury brekcjowej. Wyjaśnienia w tekście
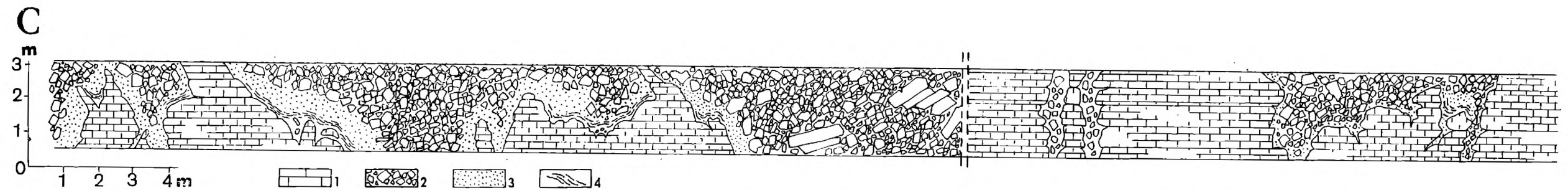

Fig. 4. Representative partial section of lower breccia zone. 1 — limestones; 2 — breccia; 3 — fine grained clastic dolomite; 4 — laminated deposits. Further explanations in text
Fig. 4. Przekrój częściowy charakterystyczny dla dolnej części struktury brekcjowej. 1 — wapienie; 2 — brekcja; 3 — drobnoziarnisty klastyczny materiał dolomitowy; 4 — laminowane osady. Dalsze wyjaśnienia w tekście
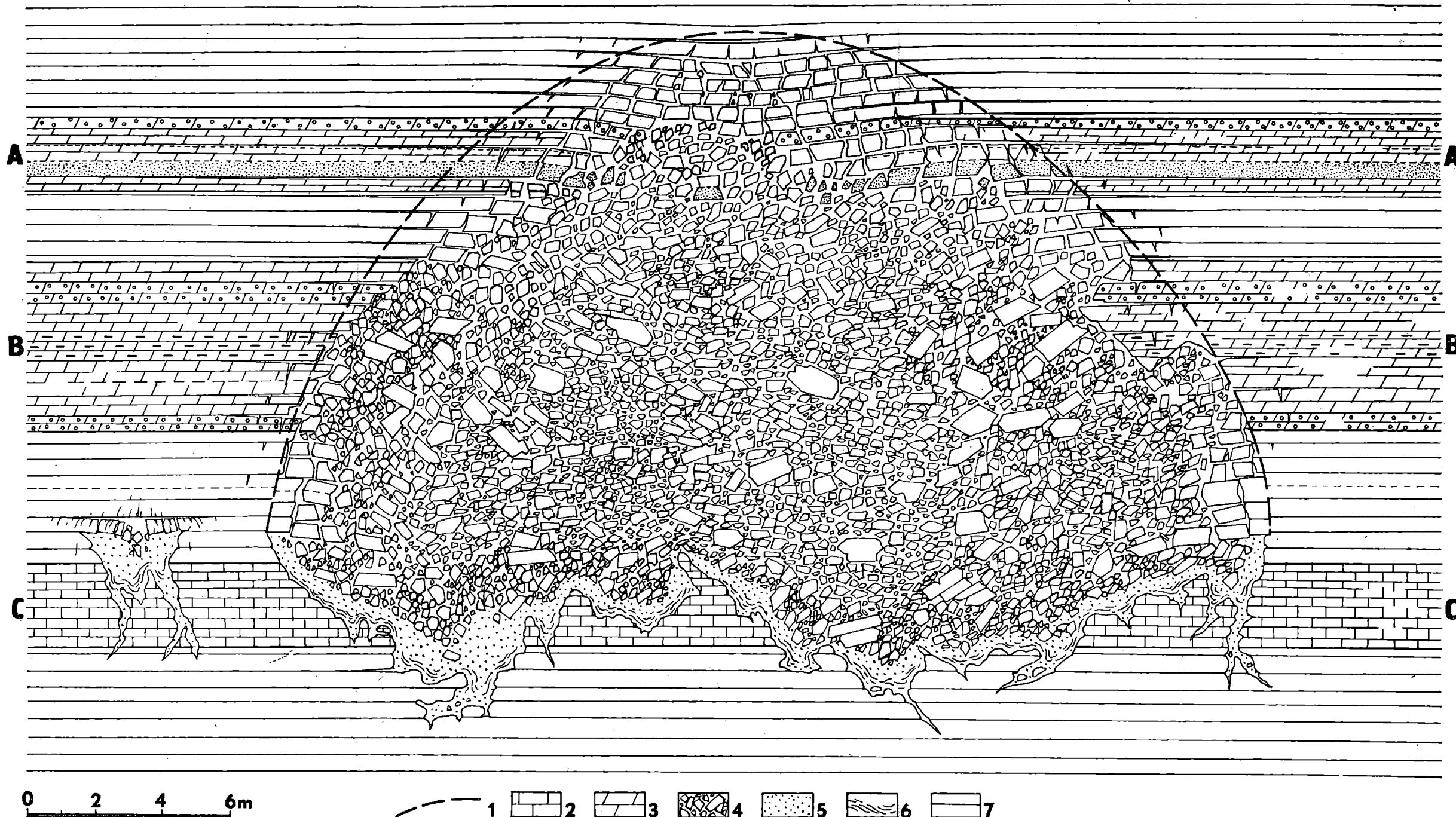
Fig. 5. Model section reconstructed on basis of partial sections. 1 — limit of pressure dome; 2 — limestones; 3 — dolomites; 4 — breccia; 5 — fine-grained clastic dolomite; 6 — laminated sediments; 7 — reconstructed unexposed parts of breccia. A, B and C refer to distinguished parts of breccia body

Fig. 5. Zrekonstruowana, na podstawie przekrojów częściowych, struktura brekcjowa. 1 — zasięg sklepienia ciśnień; 2 — wapienie; 3 — dolomity; 4 — brekcja; 5 — drobnoziarnisty klastyczny materiał dolomitowy; 6 — laminowane osady; 7 — domniemane części struktury brekcjowej. A, B i C — przekroje odpowiadające wyróżnionym częściom struktury brekcjowej — patrz tekst

ment II is an unsorted agglomeration of large slabs and small particles All these rock fragments are sharply angular. They have been shifted amongst themselves and, in places, thoroughly mixed. The larger blocks, however, tend to concentrate close to the margins of the breccia, and it is here where the amount of vertical displacement is the smallest. All the rock-fragments are obviously derived from crackle breccias or directly from the fractured walls of the undisturbed dolomites. In this connection, attention may be directed to the contact between the segment I and II. The unbrecciated dolomite forms here and overhanging, jagged wall and the detached fragments in the breccia fit well the steplike jags from which they were derived.

Z o n e C. The partial section illustrated in fig. 4 shows a typical contact between the breccia and the underlying limestone. The breccia itself shows all the properties of the previously described breccias, but the amount of vertical displacement of the dolomite fragments is difficult to asses. The breccia rests on an irregular and sharply defined solution surface that shows a typical karst topography. The solution features are controlled by fractures in limestones.

The dotted area in fig. 4 represents a fine grained detrital material that tends to concentrate at the base of the breccia bodies. This material contains a considerable amount of black argilaceous matter. Directly upon the underlying limestone there are often finely laminated sediments. These sediments consist of small dolomitic grains, rounded limey fragments and dark argilaceous matter. The karstic pockets at the base of the breccia contain also laminated ores. Such ores consist of thin layers of sphalerite grains. The ores are intercalated by thin layers of fine clastic dolomites and by argilaceous layers (see S a s s - G u s t k i e-w i c z, 1971a and 1975).

RECONSTRUCTED MODEL SECTION OF THE BRECCIA

Fig. 5 shows a reconstruction of a typical breccia body as seen in vertical cross-section. As already noted, the reconstruction was made by projecting the essentials of the partial sections discussed into one model section. The details as well as the assemblage of features revealed by the partial and model sections clearly point to a solution collapse origin of the breccia in the Olkusz region. This is in agreement with the suggestion set forth by S a s s - G u s t k i e w i c z (1970) and B o g a c z et al. (1970). The brecciation evidently took place after lithification of the ore-bearing dolomite.

It should be noted that the overall pattern of fractures, particularly within the crackle breccias, is consistent with the known concept of "pressure arch" or "pressure dome". This concept is used to define a zone of stress that is resolved in form of a dome above openings. Such pres-

sure arches are not only common in mine openings but may occur above natural caves (D a v i e s, 1951). The formation of breccias below such pressure arches restores the equilibrium of forces acting on the rock and, in absence of continuous dissolution, may prevent further roof failure. Thus the breccia represent a sort of "self-filling" that may be compared with the filling of mine workings.

Concluding these considerations it should be noted that the reconstructed model section of the breccias from Olkusz shows a striking similarity to the "high domes" described M c C o r m i c k et al. (1971) from the East Tennessee ore district. The high domes have also been interpreted in terms of the pressure arch concept and the breccias regarded as solution collapse structures.

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STRESZCZENIE

Mineralizacja cynkowo-ołowiowa w Olkuszu związana jest ściśle ze specyficznymi brekcjami. Jednakże niektóre części brekcji są w sposób widoczny pozbawione mineralizacji. Pozwala to na odrębne rozpatrywanie pochodzenia brekcji i genezy mineralizacji. Niniejsza praca przedstawia szczegółowy opis brekcji rzucający nowe światło na jej pochodzenie. Podobnie jak mineralizacja, brekcje ograniczają się do dolomitów kruszconośnych. W spągu brekcji natomiast często występują wapienie stanowiąc dolną granicę ich zasięgu. Wprowadzono pojęcie struktury brekcjowej jako części górotworu obejmującej zarówno brekcję jak i najbliższe przylegające do niej skały, które zachowują swoje pierwotne ułożenie. Wielkość struktur brekcjowych w poziomie waha się w granicach 150—300 m. Pionowe rozprzestrzenienie jest bardzo różnorodne i może osiągać 30—50 m. Figura 1 przedstawia dwa przykłady zarysów brekcji w planie, które uzyskano w drodze interpolacji danych z sieci wyrobisk. Przekrój „a" znajduje się blisko spągu struktury brekcjowej, przekrój „b" natomiast około 15—20 metrów powyżej niego. Linia ograniczająca brekcję na przekroju „a" jest bardziej nieregularna i skomplikowana niż na przekroju „b". Wynika to z faktu, że spąg brekcji stanowi powierzchnia o urozmaiconej morfologii krasowej. Nieregularny i nieliniowy kontur struktury brekcjowej oraz obecność wewnątrz brekcji reliktów nie zbrekcjowanych skał wyklucza udział tektoniki w tworzeniu się brekcji i skłania do poglądu o jej zawałowym pochodzeniu. Z wielu odsłoniętych w ko-

palni fragmentów struktur brekcjowych wybrano trzy przekroje częścio-
we, które najlepiej oddają istotne szczegóły charakterystyczne dla gór-
nej, środkowej i dolnej części struktury, a następnie rzutowano je na je-
den przekrój modelowy odtwarzający pełny przekrój struktury brekcjo-
wej w pionie. Figura 2 przedstawia przekrój częściowy, charakterystycz-
ny dla górnej części struktury brekcjowej. Pionowe przemieszczenia blo-
ków są tu niewielkie, co wskazuje, że przekrój odsłania wierzchołek
struktury zawałowej. Układ bloków na granicy brekcji z nie zaburzony-
mi dolomitami dowodzi, że zamykały one proces samopodsadzania za-
wału. Figura 3 jest przekrojem częściowym charakterystycznym dla środ-
kowej części struktury brekcjowej. Trzeci z przekrojów częściowych (fig.
4) obrazuje typowy kontakt między brekcją i podścielającymi ją wapie-
niami. Brekcja spoczywa na nie zaburzonych, poziomo leżących wapie-
niach, których powierzchnię cechuje typowa morfologia krasowa. Mię-
dzy brekcją a wapieniami znajduje się drobnoziarnisty materiał klastycz-
ny, podścielony laminowanymi osadami. Figura 5 jest obrazem zrekon-
struowanej struktury brekcjowej. Uzyskany model przekroju pionowego
struktury jasno wskazuje na zawałowy charakter brekcji w Olkuszu, ini-
cjowany przez procesy krasowe. Zrekonstruowana struktura zawałowa
wykazuje uderzającą analogię do brekcji zawałowych w amerykańskich
złożach okręgu Tennessee.

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