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Sedimentary salt megabreccias exposed in the Wieliczka mine, Fore-Carpathian Depression

ABSTRACT: Resedimentation processes played an important role in the development of the Wieliczka salt deposits, Fore-Carpathian Depression in Poland. The upper part of the Stratified Salt Member is represented by redeposited sandstones, conglomerates and pebbly mudstones composed of salt fragments and, in the southern part, also of fragments of the Miocene clays and Carpathian flysch-rocks. All these deposits build up several submarine fans thinning northwardly, off the Carpathians. The Salt Breccia Member overlying the stratified salts is thought to have resulted from mass movements of marly-clay sediments with olistholites of salt, Carpathian flysch, and Miocene rocks. Sedimentary origin of these deposits is evidenced by the presence of sedimentary structures in the stratified salts, the character of the contact between the Stratified Salt and the Salt Breccia Members, and the structure of the salt breccias.

INTRODUCTION

The purpose of this paper is to discuss the origin of salt breccias (Zuber salts) exposed in the Wieliczka mine near Cracow. The breccias in question have traditionally been interpreted in terms of tectonic deformations (TOŁWIŃSKI 1956; GAWEŁ 1959, 1962; POBORSKI & SKOCZYLAS-CISZEWSKA, 1963; GARLICKI 1968, 1977, 1979; SZYBIST 1975; WIEWIÓRKA 1977). The below presented interpretation is that the breccias are sedimentary structures produced by subaqueous gravity flows of partly unconsolidated saliferous deposits.

The Wieliczka salts are of Middle Miocene (Middle Badenian=Lower Serravallian) age and are a part of an extensive saliferous zone of the Fore-Carpathian Depression, adjacent to the northern margin of the Flysch Carpathians (Text-fig. 1). The flysch nappes are thrust over the saliferous zone, and the Wieliczka salts are disturbed by late Miocene tectonic movements consequent upon and associated with the onset of flysch nappes. The Wieliczka salts occur in three tectonic "*Schuppen*" structures, thrust one upon another and, collectively, over the autochthonous evaporites of Miocene age (Text-fig. 2).

The salt-bearing sequence of the Wieliczka mine is composed of the two units: the Stratified Salt Member, and the overlying Salt Breccia Member. The lower one is made up of distinctly stratified salts and "barren" rocks. The upper unit consists of the salt megabreccia which, in the mining nomenclature, is known as the "Zuber" salts (NIEDŹWIECKI 1883, 1884, 1886; GAWEŁ 1959, 1962).

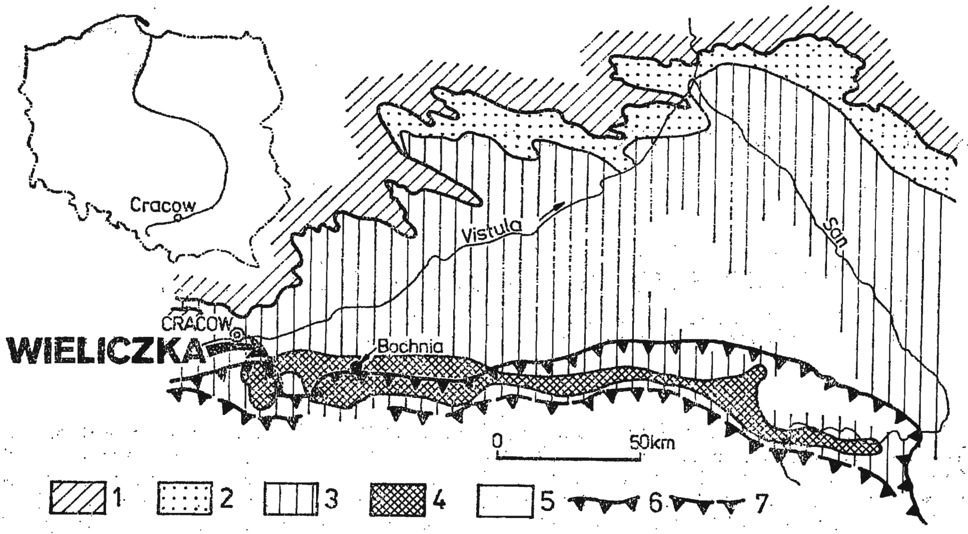


Fig. 1. Facies map of the Middle Miocene (Badenian) evaporites developed in the Fore-Carpathian Depression

1 — Mesozoic and Paleozoic substrate, 2 — littoral carbonates, 3 — sulfates, 4 — chlorides, 5 — regions without evaporites, 6 — present-day boundary of the Carpathian overthrust (*1-6* after GARLICKI 1979); 7 — supposed boundary of the Carpathians at Badenian time

DESCRIPTION AND INTERPRETATION OF SALT MEMBERS

According to previous interpretations, the contact between the above mentioned members is of tectonic character. The Zuber salts are believed to have been thrust upon the underlying stratified salts. The brecciated nature of the Zuber salts as well as the presence of local slickensided surfaces are cited as evidences to support such an interpretation (POBORSKI & SKOCZYLAS-CISZEWSKA 1963, SZYBIST 1975).

According to the present authors' opinion, the contact between the Zuber salts and the underlying Stratified Salt Member is of sedimentary nature, *i. e.* the both members are parts of the same depositional sequence and are arranged in normal stratigraphic succession. The brecciated character of the Zuber salts is explained in terms of synsedimentary gravity mass movements, as evidenced by: (*i*) sedimentary structures observed in the uppermost parts of the Stratified Salt Member, (*ii*) the character of the contact between the two members, and (*iii*) the character of the Zuber salts themselves.

Ad (*i*): The upper part of the lower member, *i.e.* the so-called „Spiza" salt, is composed of detrital salt layers showing occasionally graded bedding or cross-lamination and sporadic intercalations of marls and mudstones with planktic foraminifera (Pl. 1, Fig. 1). Important is fact that in southern regions of the Wieliczka mine there are intercalations of Zuber-like breccias of unquestionable sedimentary origin (Text-fig. 3 and Pl. 1, Fig. 2; *see also* CHARYSZ & WIEWIÓRKA 1976). There are (*e.g.* in the Thinfeld and Gruszczyn Galleries) also slump structures (Pl. 2, Fig. 1), lenses of pebbly saltstones (Pl. 2, Fig. 2) or coarse clast-supported conglomerates occasionally grading upwards into laminated salts (Text-figs 4—5 and Pl. 3).

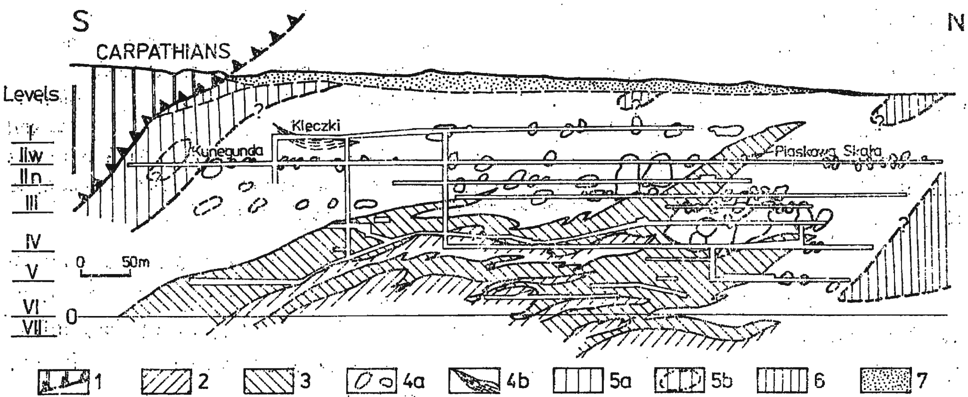


Fig. 2. Transverse section of the Wieliczka Salt Mine (*after* GAWEŁ 1959; *modified*)
1 — Carpathian nappes, **2** — Miocene clays (substrate of salt deposits), **3** — layered salt (Stratified Salt Member), **4a** — breccia with salt blocks (Zuber = Salt Breccia Member), **4b** — lenses of laminated saltstones in the Salt Breccia Member, **5a** — redeposited deposits rich in fragments of flysch rocks, **5b** — big olistholite of flysch rocks, **6** — Upper Badenian (Grabovian) deposits, **7** — Quaternary

The Zuber-like breccias consist of an unsorted mixture of boulders of salt and anhydrite, clasts of the Miocene clays, and flysch-derived rock fragments up to 30 cm in diameter. Matrix consists of marls, salt and clay. The conglomerates and pebbly saltstones contain intrabasinal clastics comprising salts, marls and sandstones of early Badenian age and such fragments of flysch rocks (Pl. 4, Figs 1—2 and Pl. 5, Fig. 1) as the Istebna sandstones, Lgota glauconitic sandstones, Upper Cretaceous variegated marls, and Lower Cretaceous black shales. There also occur shells of mollusks, corals, and abundant remnants of carbonized plants (ZEJSZNER 1843—61, NIEDŹWIECKI 1883—86, ZABŁOCKI 1928—30, ZABŁOCKA 1931, KRACH & *al.* 1974, KOLASA 1982, ŁAŃCUCKA-ŚRODONIOWA 1984). The matrix of pebbly saltstones consists of salt, clay minerals, and quartz grains. The marly intercalations between bodies of breccias and conglomerates (exposed *e.g.* in the Thinfeld Gallery) have yielded benthic and planktic foraminifera similar to those found in marls underlying the salt rocks sequence of the Wieliczka mine (ŁUCZKOWSKA 1978). This fauna is indicative of Lower Badenian age (Zone with *Candorbulina suturalis & Uvigerina costai*).

The Zuber-like breccias are tapering rapidly morthwards. The conglomerates which still can be traced in this direction consist exclusively of rounded fragments and grains of crystalline salts (Pl. 5, Fig. 2) and pass gradually into salt sandstones (Pl. 6, Figs 1—2). In general, the amount of fine-grained sediments in the uppermost part of the lower member visibly increases northwards.

Ad (*ii*): Neither large-scale thrust surfaces nor wast slickensided surfaces have been observed along the boundary between the two members (Text-fig. 4; Pl. 6, Figs 1—2 and Pl. 7, Fig. 1). The slickenside surfaces reported by earlier authors are local and occur chiefly on the crests of the "*Schuppen*" structures. This boundary is generally sharply delineated and local irregularities are here interpreted in terms of subaqueous erosion or bar systems.

Ad (*iii*): Salt Breccia Member (Zuber salts) is made up of matrix-suspended array of rock fragments and blocks varying in size, composition and shape (Pl. 7 Fig. 2; Pl. 8, Figs 1—2; Pl. 9, Figs 1—2). The basin-derived clastic components predominate, and they consist of rocksalt and the associated marls, clays, mudstones and sandstones. The largest and most common components are those made up of salts. The salt blocks are angular, subangular and occasionally ball-like. Some of them attain very large dimensions measured in thousand or hundreds of cubic meters. In one of the huge blocks the world-famous Chapel of Blessed Kinga has been sculptured (Text-fig. 6). The blocks are composed of rocksalt, laminated, "stained-glass window" type, as well as of calcite- and dolomite-bearing salts (PROHAZKA & *al.* 1959; GAWEŁ 1962; GARLICKI 1968, 1979; SZYBIST 1975). The salt boulders are sometimes surrounded by thin layers of secondary anhydrite, gypsum grappers and fibriform salt (NIEDŹWIECKI 1883—86, SZYBIST 1975). The flysch-derived clastic components are much smaller (up to 1 m), and their composition is similar to that of the already mentioned "Zuber-like" breccias and conglomerates within the Spiza salts with addition of the Paleogene shales from the Carpathians. The fragments of Miocene clays, mudstones and sandstones commonly show soft-rock deformations (slumpballs, *see* Pl. 9, Figs 1—2). The matrix consists of marls, clay, salt and grains. Because of the superimposed tectonic deformations upon the breccia body, some of the blocks show evidence of postdepositional rotation.

In general, the structure of the Salt Breccia Member (Zuber salts) is that of a chaotic olisthostrome. Occasionally some kind of preferred orientation of blocks is observed. The largest blocks tend to concentrate in a region which has subsequently become the central part of the Wieliczka mine field. Some of the blocks are imbricated with *A—B* planes plunging southwards. In the lowermost part of the breccia body a number of slab-shaped blocks are oriented parallel to the bottom surface of the breccia. Locally the size of blocks and the amount of matrix clay decrease so that the breccia consists of self-supported smaller fragments (*e. g.* in the Eichmüller, Franciszek, Tyrol and Taras Galleries; *see* Pl. 10, Figs 1—2). Spo-

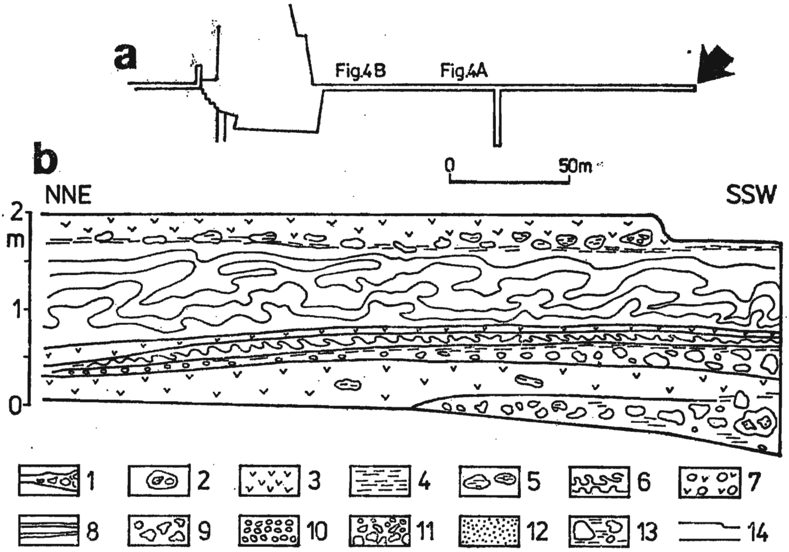
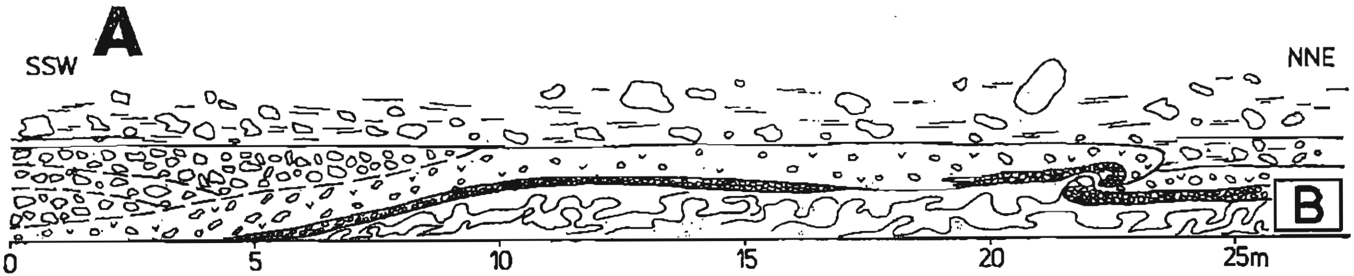


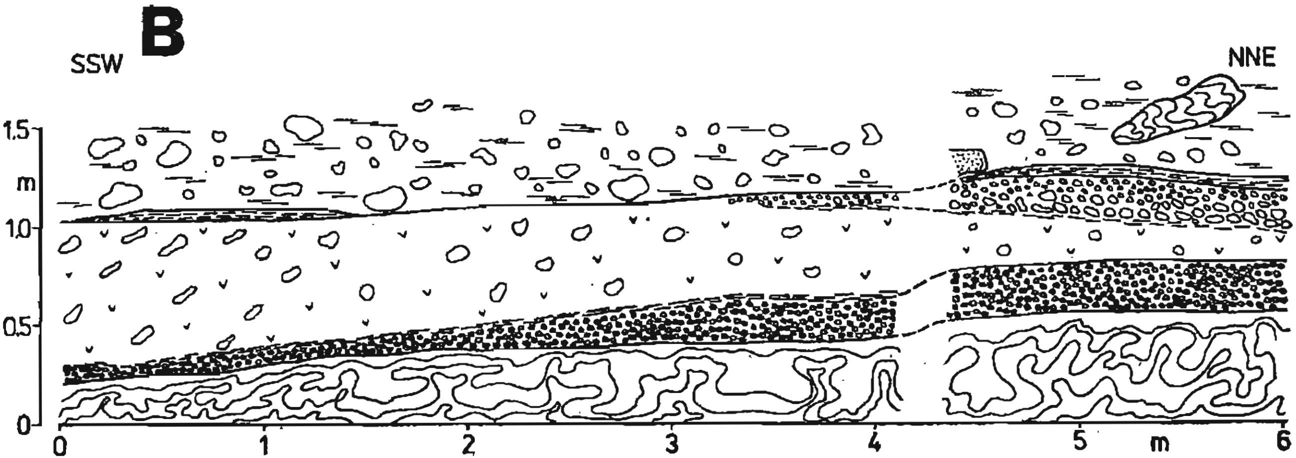
Fig. 3

a — Location of the exposures presented in Text-fig. 3b (*arrowed*) and Text-fig. 4*A—B*
b — Section exposod in the east wall near the southern endgate of the Thinfeld Gallery
1 — Lenses of Zuber-like deposits in the uppermost part of the Stratified Salt Member, 2 — Miocene clays with fragments of older rocks, 3 — saltstone, 4 — clay and mudstone, 5 — fragments of clays, 6 — salt with slump structures, 7 — pebbly saltstone, 8 — laminated saltstone, 9 — conglomerate, 10 — saltstone built of salt fragments (up to 1 cm in diameter) 11 — graded conglomerate, 12 — sandy mudstone, 13 — breccia deposits, olisthostrome (Zuber = Salt Breccia Member) 14 — galleries

Contact between the Stratified Salt Member and the Salt Breccia Member

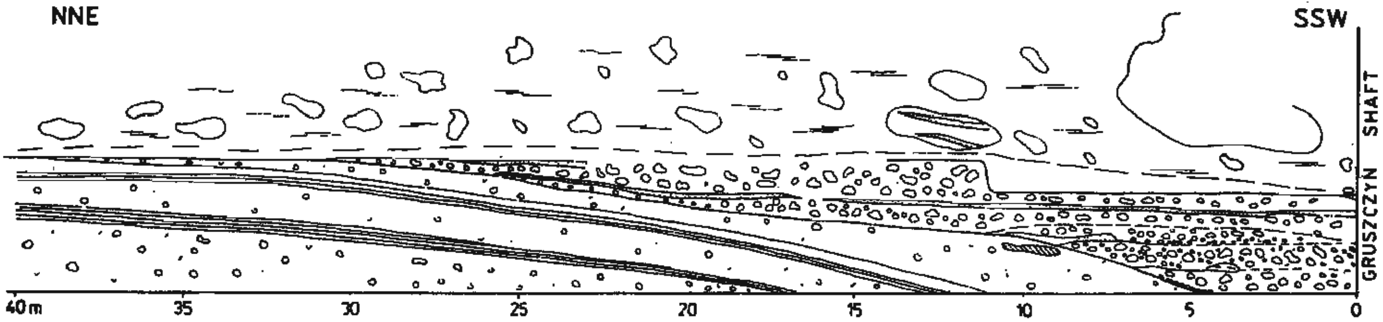
A — Exposed in the western wall of the Thinfeld Gallery, B — Detail of the same contact (for location and explanations *see* Text-fig. 3)

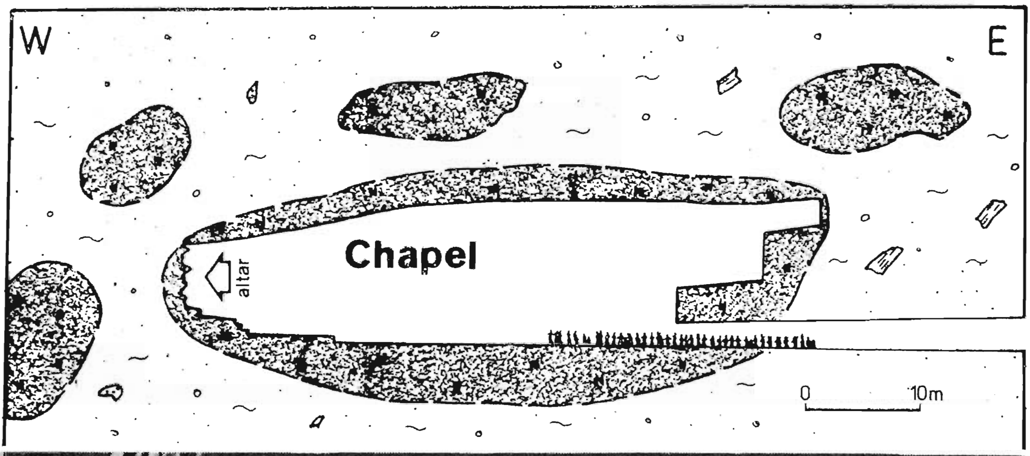


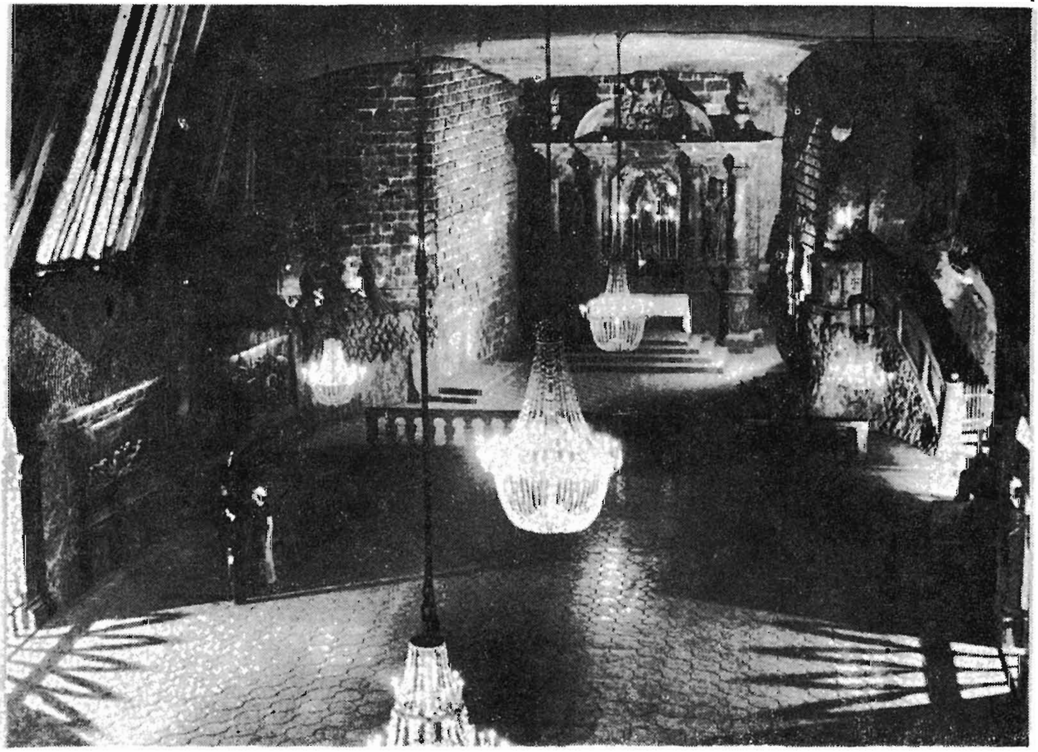


Contact between the Stratified Salt Member and the Salt Breccia Member

Contact exposed in the western wall of the Gruszczyn Gallery (for explanations *see* Text-fig. 3)







The **Chapel of Blessed Kinga** in the Wieliczka Salt Mine

The Chapel is excavated inside one of the salt blocks (olistholites) of the Salt Breccia Member (*cf.* Text-fig. 2)

Photo facing the west; *taken by* A. DŁUGOSZ

The **Chapel of Blessed Kinga** is a paramount part of this medieval mine which since the last century has become an unforgetable attraction for tourists, both as one of the most famous wonders of human activity in past ages, and as the cradle of Polish mining art. The Wieliczka Salt Mine, together with its Old Mining Exhibition (founded by A. Długosz), was introduced in 1978 into the UNESCO World List of the Cultural and Natural Heritage.

radically (*e. g.* in the Kłęczki Chamber), the breccia passes upwards into laminated saltstones (Text-fig. 7 and Pl. 11, Figs 1—2; *cf. also* ŚLĄCZKA & KOLASA 1985).

The Zuber salts (*e. g.* in the Kunegunda, Eichmüller, Tyrol and Leszno Galleries) are overlain by partly stratified sand-marly clays containing abundant fragments

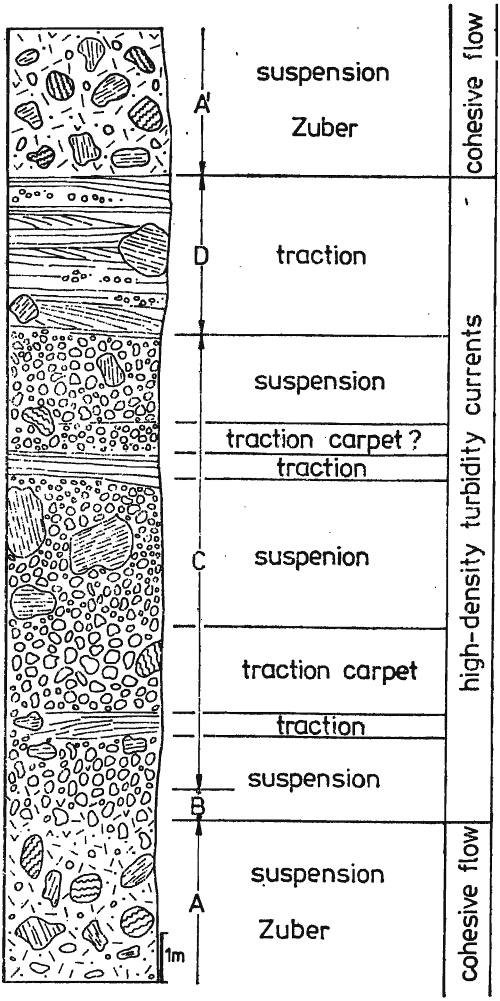


Fig. 7

Sequence of divisions (*A-D*) deposited by a cohesive flow passing upwards into high density turbidity currents (*based on*: LOWE 1982), as exposed in the Kłęczki Chamber

A'—bottompart of the overlying sequence
D — laminated salt sandstone
C — salt conglomerate
B — muddy salt conglomerate
A — Breccia deposit (Zuber)

of flysch rocks (Pl. 12, Figs 1—2) represented by Upper Cretaceous variegated marls (ALEXANDROWICZ 1975, ZAPAŁOWICZ 1975), Albian black shales (S. GEROCH, *oral information*) as well as sandstones similar to the lower Istebna sandstones (Tomaszkowice sandstones), and glauconitic sandstones of the Lgota type. All these fragments are angular to subrounded and usually up to 1 meter in size, but sometimes their dimension may reach several metres. Apart of flysch rocks there are fragments of the Miocene marls probably derived from the salt substrate. The salt blocks are here notably absent.

The sedimentary origin of some deposits exposed in the Kunegunda Gallery has already been recognized (NIEDŹWIECKI 1883—86, GAWEŁ 1962, ALEXANDROWICZ 1975), but according to the present authors' observations the whole profile exposed in this gallery represents redeposited sediments.

CONCLUSIONS

One can distinguish two periods in the development of the Wieliczka salt deposits: (*1*) period of relatively quiet evaporite sedimentation and (*2*) period of intensive gravity mass movements. In the beginning of the first period a regular evapo-

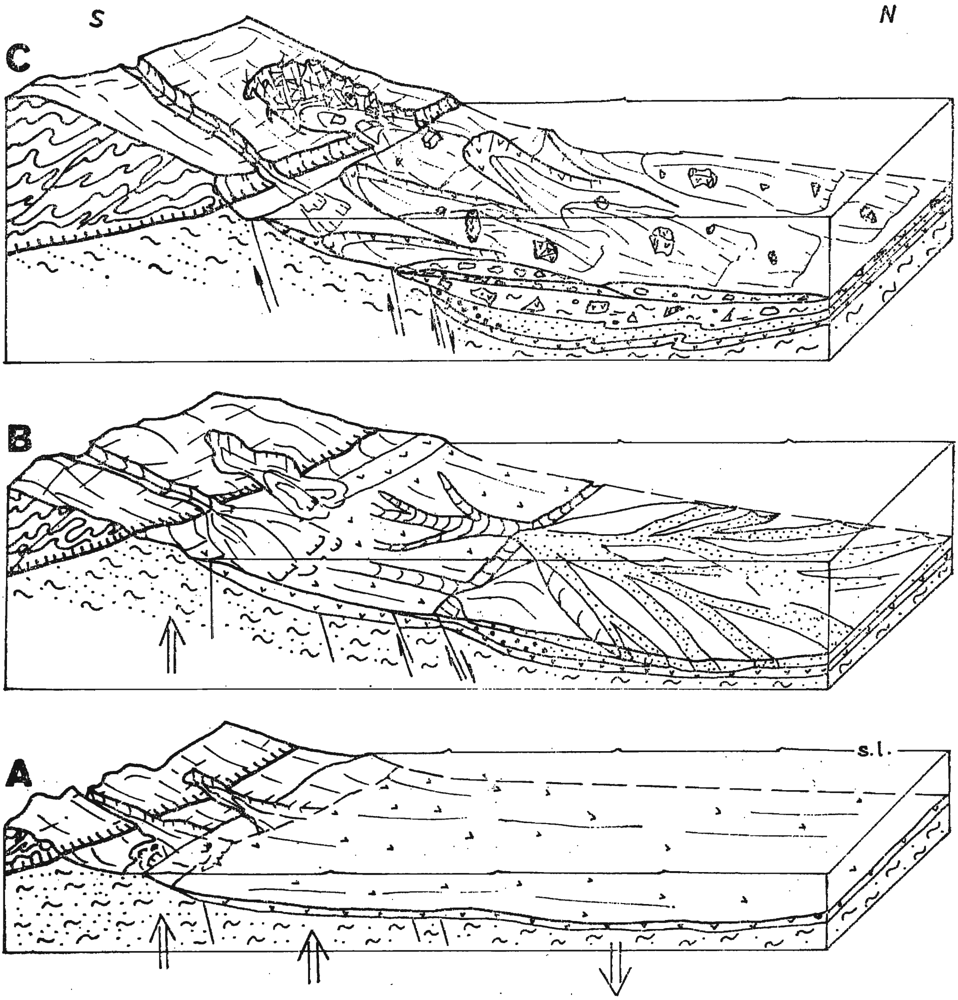


Fig. 8. Model of sedimentation of the Miocene salt formation of Wieliczka

Stage A — lower part of the Stratified Salt Member
Stage B — upper part of the Stratified Salt Member
Stage C — Salt Breccia Member

rite deposition took place both in the central part of the Wieliczka basin and in its southern part (Stage *A* in Text-fig. 8). There is sporadical intercalation of redeposited sediments only. The presence of the same tuff layers and salts (among them dolomitic salts) points to synchroneous deposition both in the southern and central parts of the basin (*see* GAWEŁ 1962, GARLICKI & *al.* 1968—81, WIEWIÓRKA 1977, KSIĄŻEK & *al.* 1980).

At the close of the first period, due to tectonic movements the basin became unstable as indicated by sedimentary structures in the upper part of the Spiza salts (slump deposits, graded bedding, debris flows, *etc*). In that time clastic submarine fans built up mainly by salt fragments developed; in all these fans proximal and distal parts are well distinguishable (Stage *B* in Text-fig. 8). The slumps, graded bedding, and first debris flows in the Spiza salt heralded the onset of large-scale gravity mass movements which brought the appearance of the Zuber salts (Stage *C* in Text-fig. 8). The absence of any discontinuity surfaces within the Zuber salts does not give a clear answer to the question whether one or more gravity movements were involved. However, the latter possibility seems to be more plausible, as indicated by the presence of the salt clast-supported conglomerates and laminated saltstones. The alimentary area for clastics was situated in the south and the debris ladden flows moved generally northwards (KOLASA & ŚLĄCZKA 1984). Towards the close of the second period only flysch material and barren Miocene sediments were involved in mass movements. Consequently, an interfingering

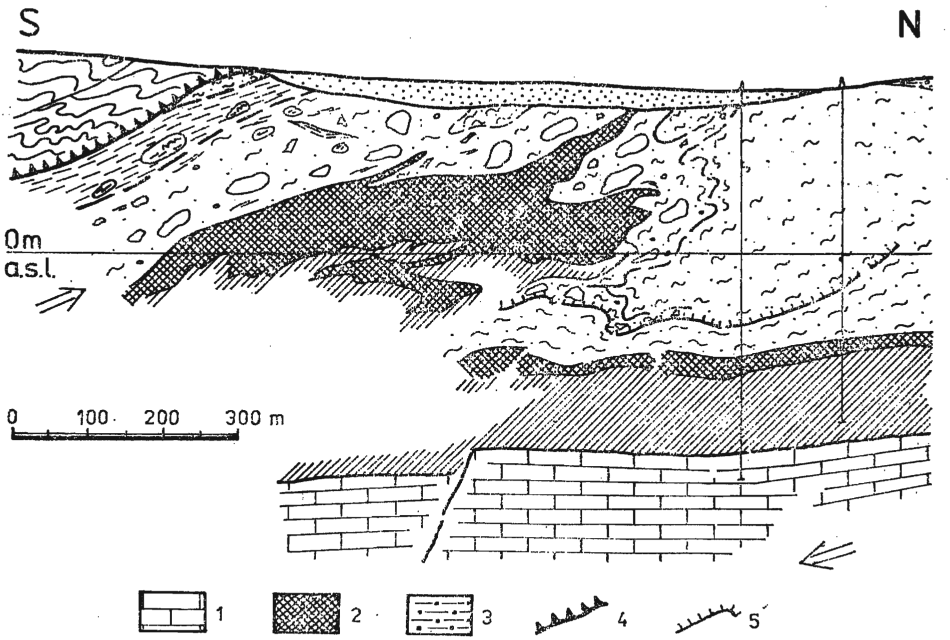


Fig. 9. Section throughout the Wieliczka Salt Mine (*compare* Text-fig. 2), to show present-day situation of the Miocene salt formation, resulting from an interaction between mass movements and the tectonics

1 — Mesozoic platform, **2** — evaporite deposits (salt and gypsum), **3** — Chodenice Beds (Upper Badenian), **4** — Carpathian overthrust, **5** — local overthrust of flysch and saline deposits is interpreted in terms of sedimentary processes, more precisely, in terms of the development of olisthostromes, and huge blocks of salts and of flysch rocks are regarded as olistholites (*see also* KUHL 1932).

A considerable part of the Spiza salt and the Zuber salts was laid down in a relatively deep water (compare model of SCHMALZ 1969). This is indicated by the character of foraminifera in the underlying and interfingering sediments. The foraminifer fauna contains species indicative of relatively deep water (ŁUCZKOWSKA 1978) and open sea environment (E. ŁUCZKOWSKA, *oral information*). No signs of shallowing have been observed, and all the shallow-marine foraminifera as well as the macrofauna (corals, mollusks, crustaceans, echinoderms; *see* REUSS 1867) are evidently redeposited.

In the present authors' opinion the so-called "Zuber" formation known from the Bochnia Salt Mine (*see* Text-fig. 1) as well as an analogous Permian formation from the Inowrocław area (northern Poland) represent the olisthostromes which is contrary to the previous opinions (POBORSKI 1978, PAWLIKOWSKI & STASIK 1980). The flysch intercalations in the Bochnia Salt Mine are supposedly of the same origin.

Gravity induced mass movements sometimes with salt olistholites, are known from the Miocene sediments in other parts of the Fore-Carpathian Depression (POŁTOWICZ 1977, 1978; ŚLĄCZKA 1977), and the occurrence of redeposited sediments with olistholites within evaporitic sequences is quite common. The sedimentary origin of blocky salt in the East-Carpathian Foreland was already indicated in Rumania (SANDULESCU & *al.* 1980).

The slumps with anhydritic olistholites are also known from the Upper Permian (Zechstein) of the southern margin of the Harz Mts (MEIER 1977). Similar olisthostromes of Miocene age have been reported from Sicily (CATALANO, RENDA & ŚLĄCZKA 1976) and the Apennines (PAREA & RICCI-LUCCHI 1972, MUTTI & RICCI-LUCCHI 1975).

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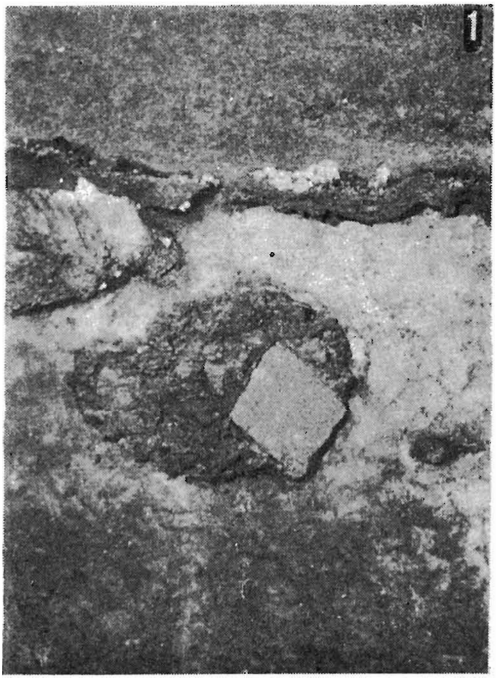
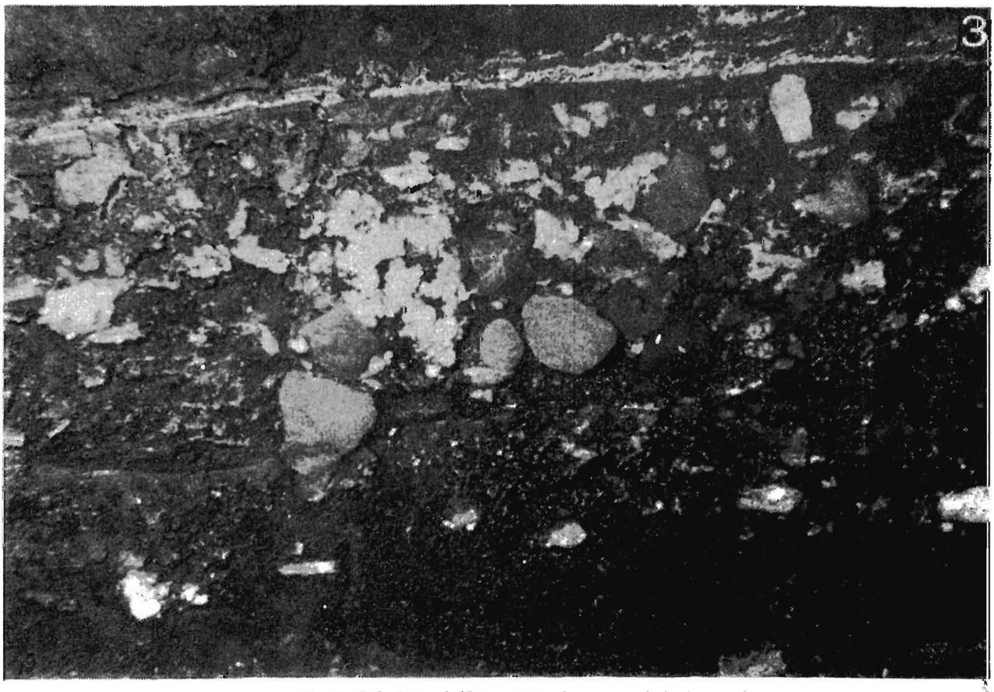
K. KOLASA i A. ŚLĄCZKA

GENEZA ZŁOŻA BRYŁOWEGO (ZUBER) W KOPALNI SOLI WIELICZKA

(Streszczenie)

Badania prowadzone nad solami spiżowymi (górna część złoża pokładowego) oraz złożem bryłowym (zuber) w kopalni soli Wieliczka wskazują, że złoże bryłowe jest pochodzenia sedymentacyjnego i stanowi efekt kontynuowania się procesów sedymentacyjnych zapoczątkowanych w czasie tworzenia się złoża pokładowego. Sole spiżowe (fig. 1—5 oraz pl. 1—5) w swojej przeważającej części są osadem redeponowanym, a struktury sedymentacyjne wskazują, iż znaczna ich część została osadzona przez spływy gęstościowe, głównie prądy zawiesinowe i osuwiska podmorskie pochodzące z podnoszącej się południowej części panwi solnej. W wyniku tych procesów rozwinął się szereg podwodnych stożków wyklinowujących się ku północy (fig. 8) z wyraźnie wykształconymi częściami proksymalnymi. Okresowo panowały w basenie warunki normalnego zasolenia, o czym świadczy występowanie we wkładkach marglistych pomiędzy ławicami solnymi (pl. 1, fig. 1) zespołów otwornicowych (z *Uvigerina costai*) o charakterze zbliżonym do otwornic z iłów podsolnych. Leżące wyżej złoże bryłowe (zuber) zostało utworzone przez szereg wielkoskalowych osuwisk podmorskich bezpośrednio nad złożem pokładowym (fig. 8). Na kontakcie pomiędzy solami spiżowymi a złożem bryłowym nie stwierdzono występowania śladów większych przesunięć tektonicznych (fig. 4—5; pl. 6 oraz pl. 7. fig. 2), a sam zuber posiada cechy brekcji olistostromowej (pl. 7, fig. 3 oraz pl. 8—9). Wszystkie bloki solne, łącznie z blokiem, w którym znajduje się kaplica Bł. Kingi (fig. 6), są olistolitami pochodzącymi z południowej części panwi solnej. Lokalnie ławice brekcji sedymentacyjnej przechodzą w zlepieńce i laminowane arenity solne (fig. 7 oraz pl. 10—11). Złoże bryłowe przykrywa w południowej części kopalni kolejny kompleks olistostromowy, pozbawiony jednak fragmentów soli, a zawierający liczne bloki pochodzące z fliszu karpackiego (pl. 12). Nasilenie się tych procesów resedymentacyjnych związane było prawdopodobnie ze zwiększającą się aktywnością tektoniczną pod koniec dolnego badenu.





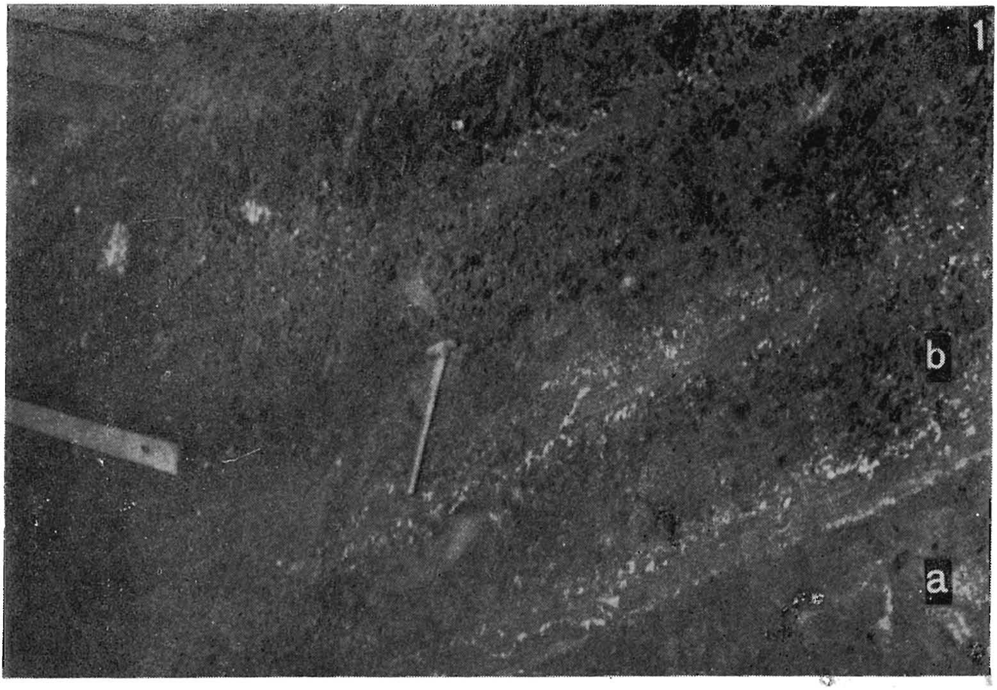
1 — Layer of marl (2 cm thick) with planktic foraminifera, separating two salt beds; at the top of lower bed a block of Miocene marls with redeposited fragments of flysch rocks (sandstones, red marls) is visible; upper part of the Stratified Salt Member; Thinfeld Gallery (*photo by* W. ZALEŃSKI)

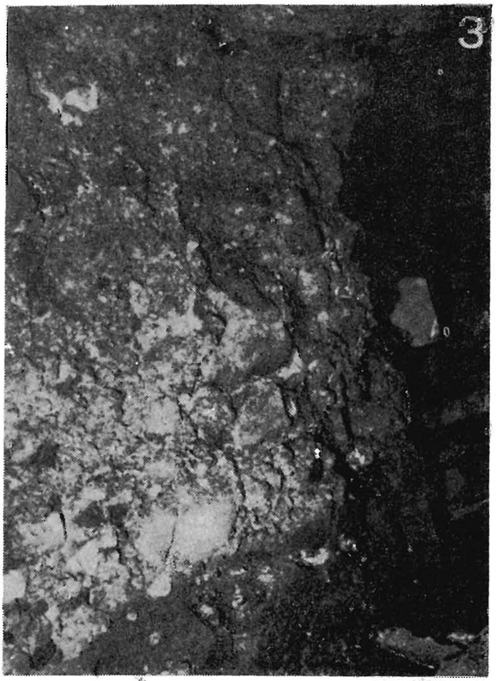
2 — Detrital salt layer with a block of marl (length 20 cm); Thinfeld Gallery (*photo by* W. ZALEŃSKI)

3 — Intercalation of the Zuber-like deposit (40 cm thick) within the Stratified Salt Member; Thinfeld Gallery (*photo by* W. ZALEŃSKI)

1 — Synsedimentary slump of salt layers covered by pebbly saltstone; upper part of the Stratified Salt Member; Thinfeld Gallery (*photo by* W. ZALEŃSKI)

2 — Pebbly saltstone with fragments of Miocene and flysch rocks, covered by salt conglomerate; uppermost part of the Stratified Salt Member; Thinfeld Gallery (*photo by* W. ZALEŃSKI)

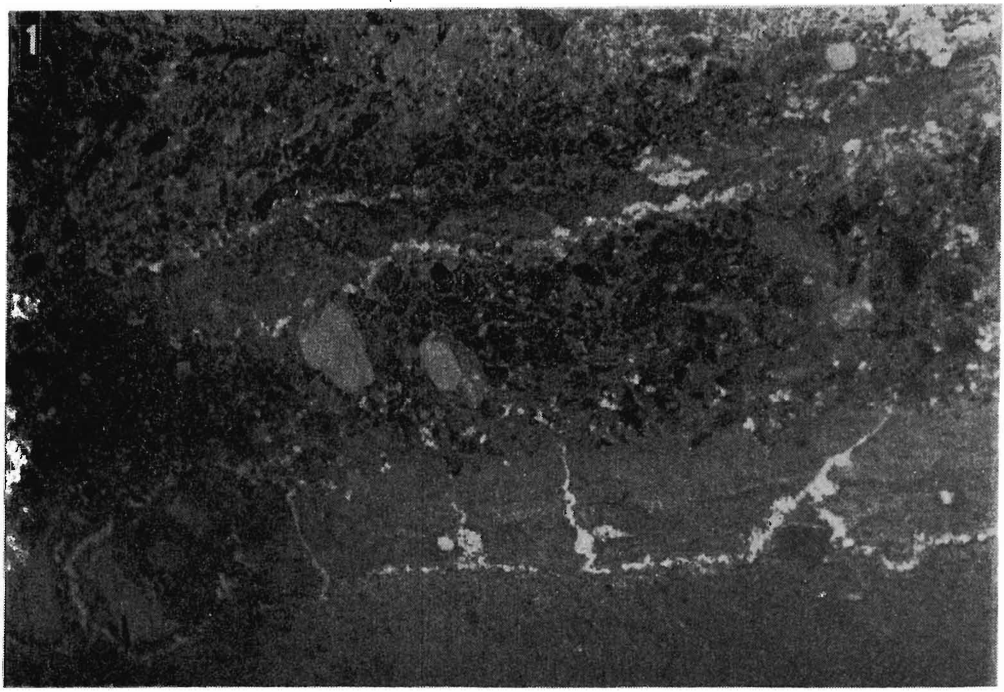


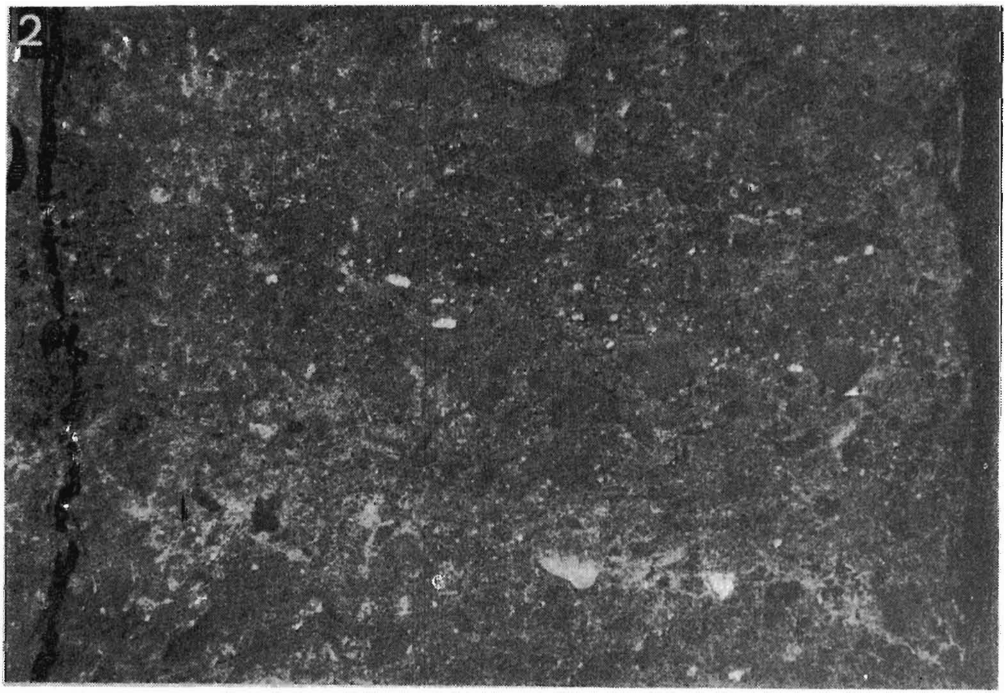


1 -- Top part of the Stratified Salt Member: a — pebbly saltstone, b — layers of conglomerate (wedging out towards the right); Gruszczyn Gallery (*photo by* W. ZALEŃSKI)

2 — Uppermost part of the Stratified Salt Member (conglomerate composed of salt blocks) and contact with the Salt Breccia Member; Gruszczyn Gallery (*photo by* W. ZALEŃSKI)

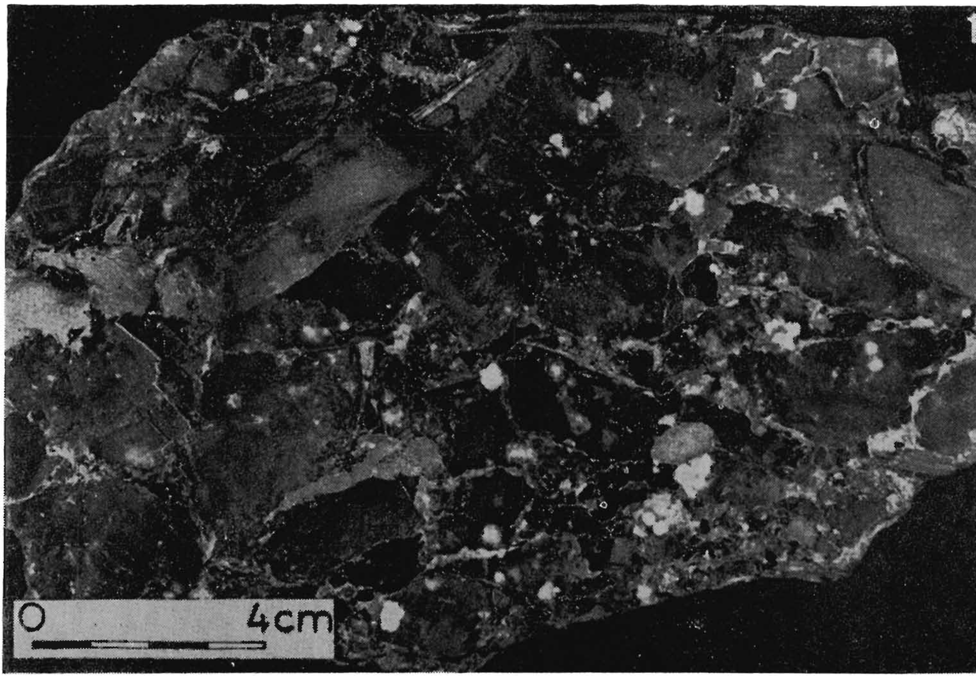
3 — Sedimentary breccia (blocks up to 20 cm) filling a depression in the layer of pebbly mudstone; uppermost part of the Stratified Salt Member; Thinfeld Gallery (*photo by* W. ZALEŃSKI)





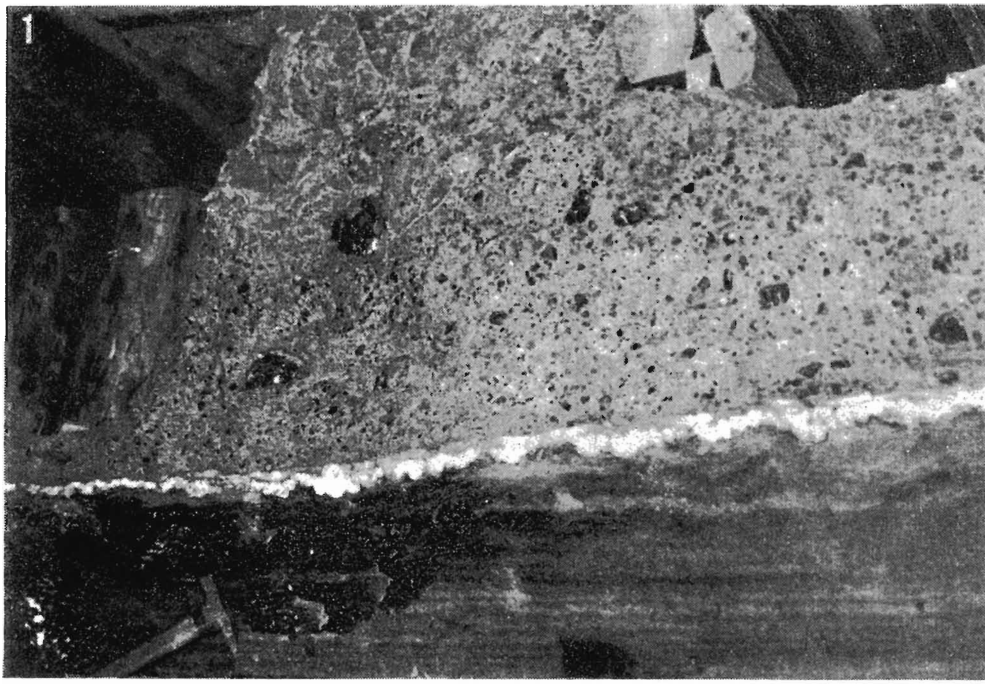
1 — Detail of the lowermost part (*b* in Pl. 3, Fig. 1) of the conglomeratic layer (*photo by* W. ZALEŃSKI)

2 — Internal structure of conglomerate with normal and reversed gradation (blocks up to 15 cm); Gruszczyn Gallery (*photo by* W. ZALEŃSKI)



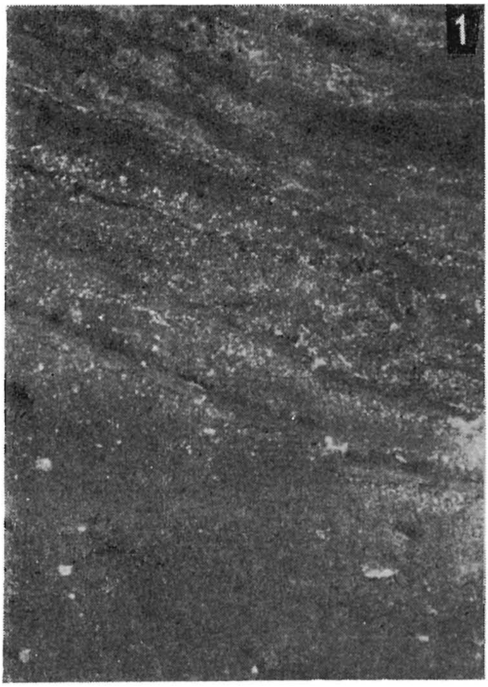
1 — Detail of the conglomerate (*see* Pl. 4, Fig. 2) composed of broken crystals of halite, anhydrite (*light grains*), and flysch rocks; Gruszczyn Gallery (*photo by* K. FEDOROWICZ)

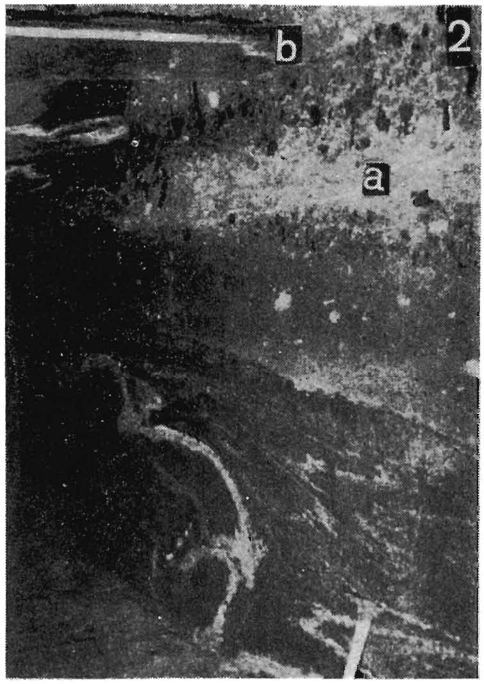
2 — Conglomerates and laminated sandstones composed of salt fragments and anhydrite particles (*light in color*): reversed gradation is visible; upper part of the Stratified Salt Member in the central part of the Wieliczka Mine; Kaniów Gallery (*photo by* W. ZALEŃSKI)

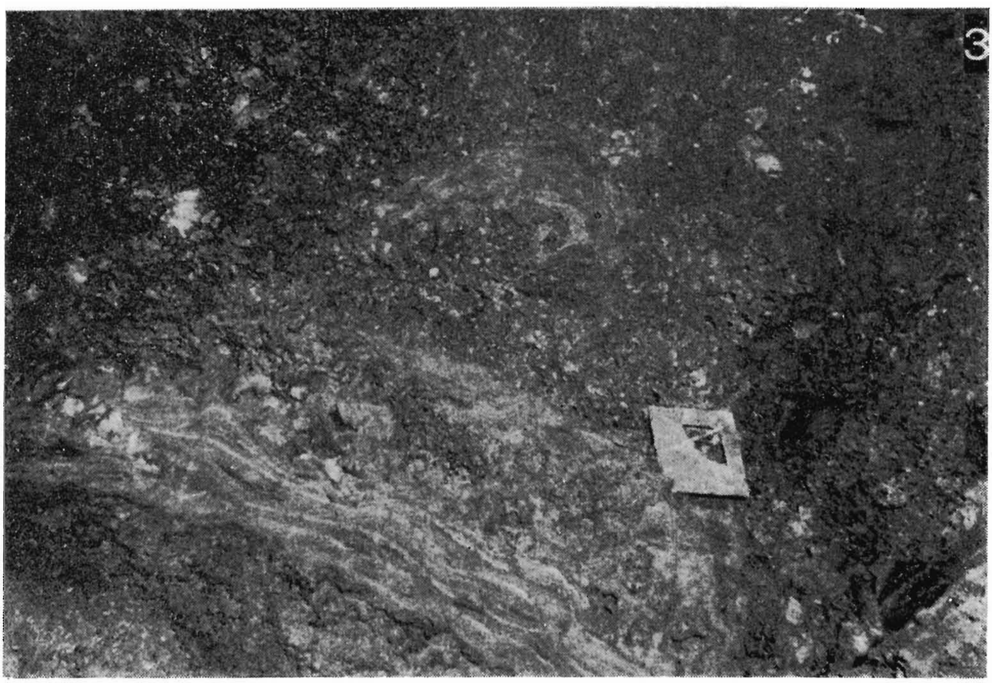


1 — Uppermost part of the Stratified Salt Member and its contact with the Salt Breccia Member in the northern part of the Wieliczka Mine; Kaniów Gallery (*photo by* W. ZALEŃSKI)

2 — Similar situation in Rarańcza Gallery (*photo by* W. ZALEŃSKI)



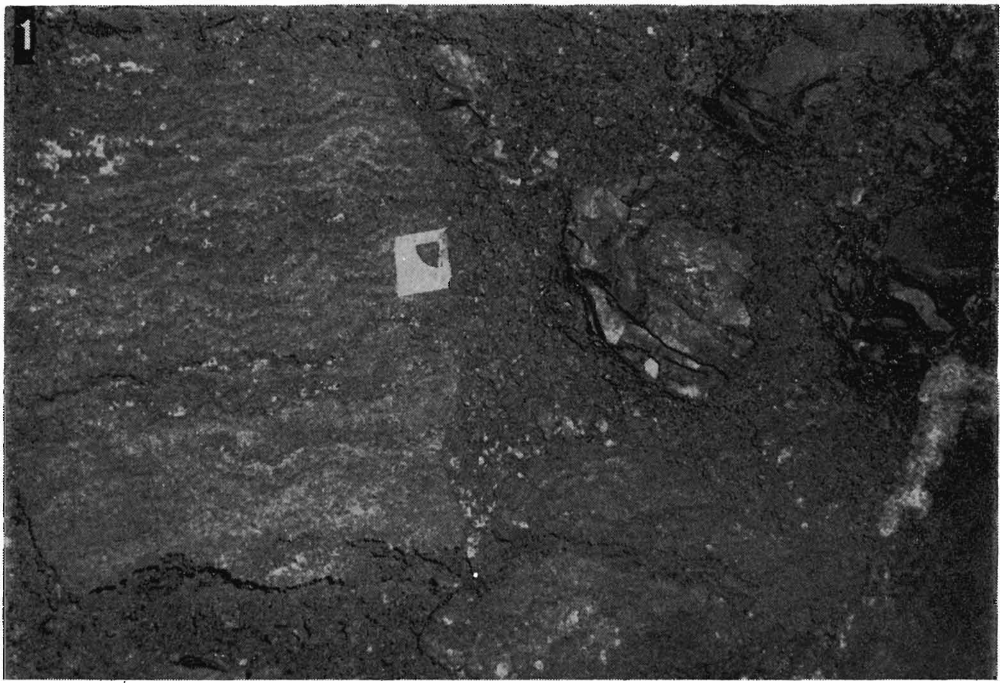


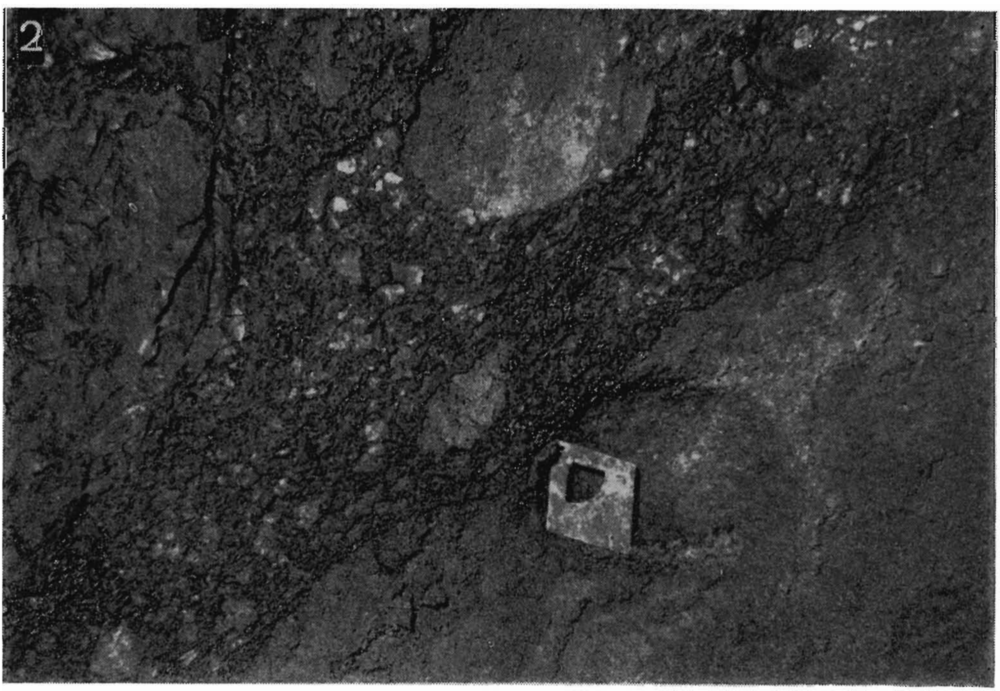


1 — Laminated saltstones (layers up to 20 cm) in the uppermost part of the Stratified Salt Member (*photo by* W. ZALEŃSKI)

2 — Contact between the Stratified Salt (*a*) and Salt Breccia (*b*) Members in the southern part of the Wieliczka Mine; Thinfeld Gallery (*photo by* W. ZALEŃSKI)

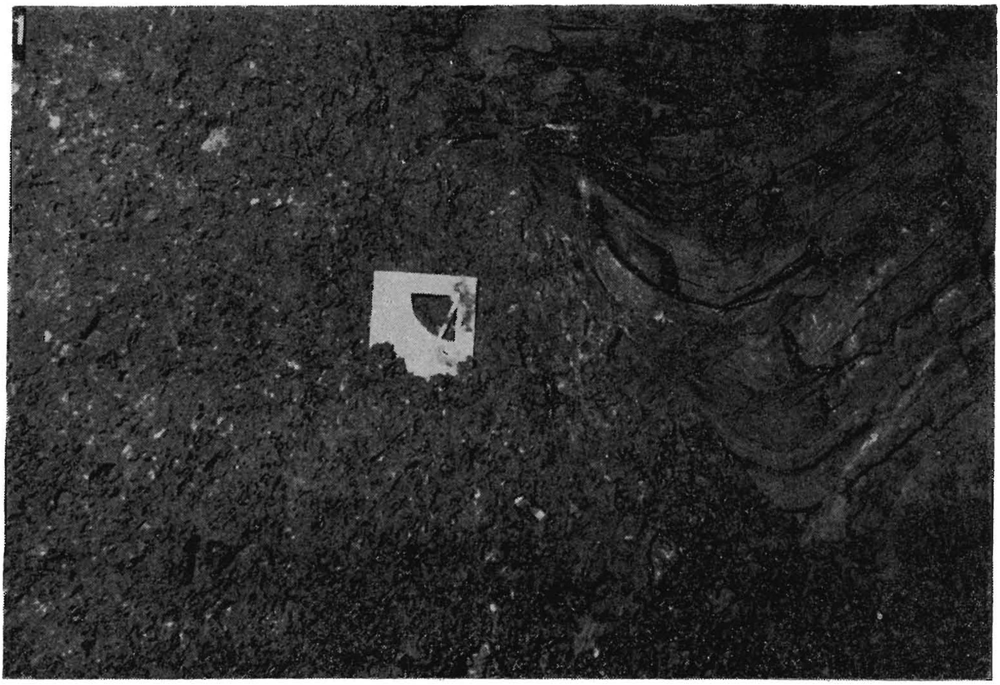
3 — Slump deposit with blocks of salt (laminated) and Miocene marls in the Salt Breccia Member; Kunegunda Gallery (*photo by* W. ZALEŃSKI)



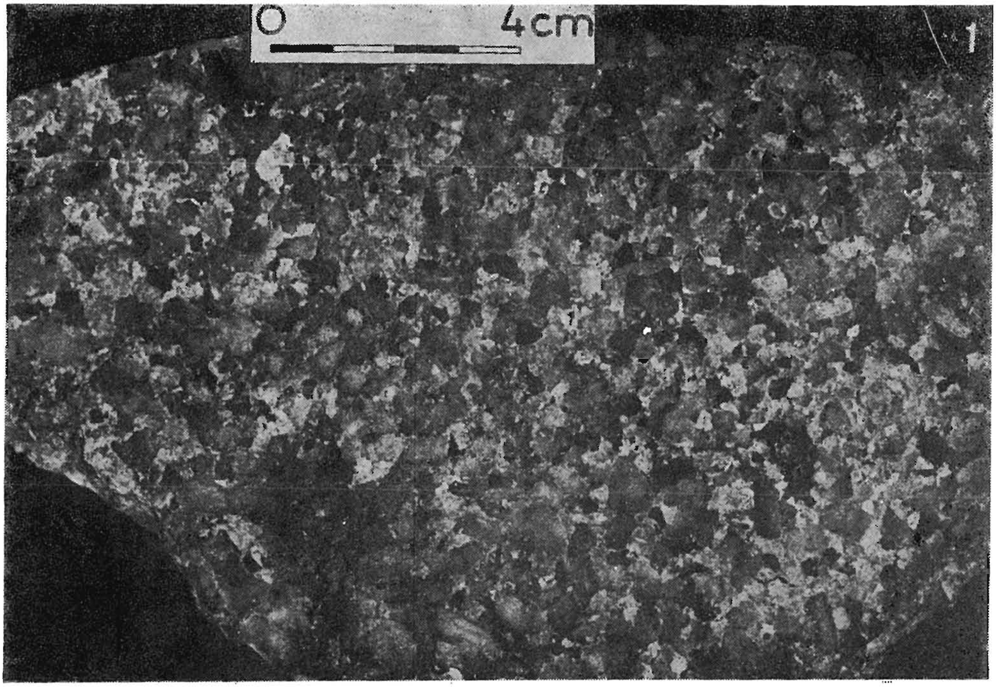


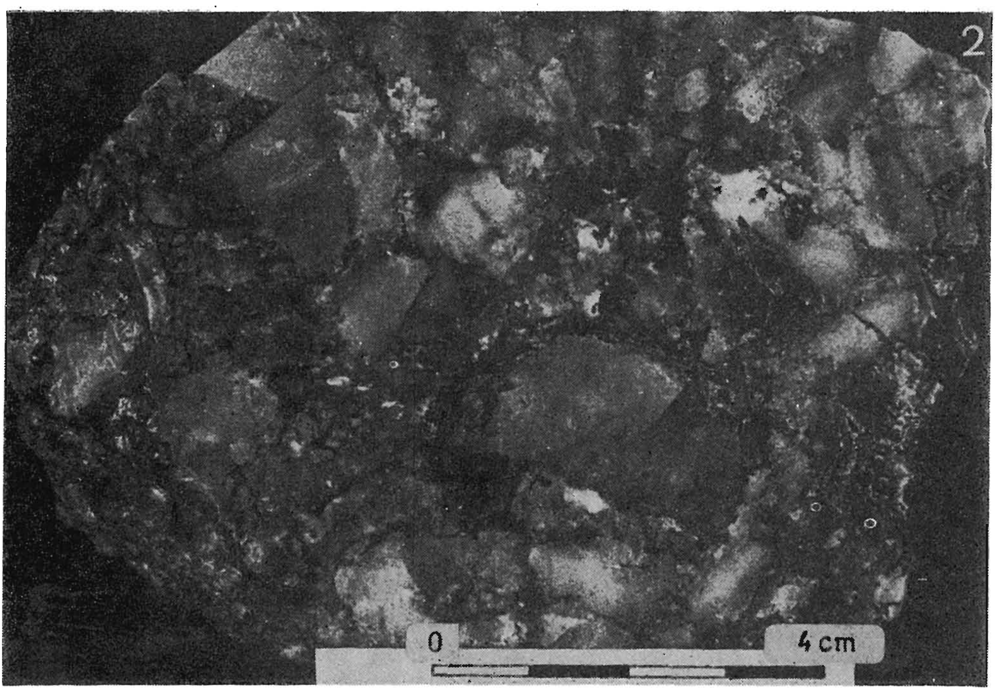
1 — Slump deposit with blocks of salt (laminated) and Miocene marls; Kunegunda Gallery (*photo by* W. ZALEŃSKI)

2 — Slump deposit with fragments of halite crystals in muddy matrix; Kunegunda Gallery (*photo by* W. ZALEŃSKI)



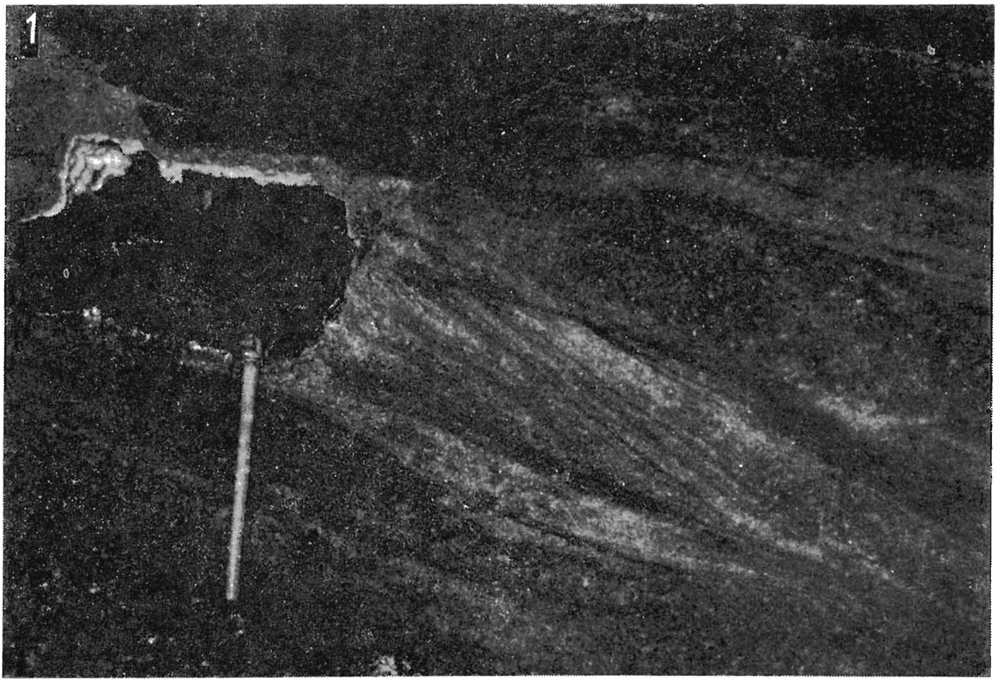
1-2 — Slump balls in the Salt Breccia Member; Kunegunda Gallery (*photos by* W. ZALEŃSKI)

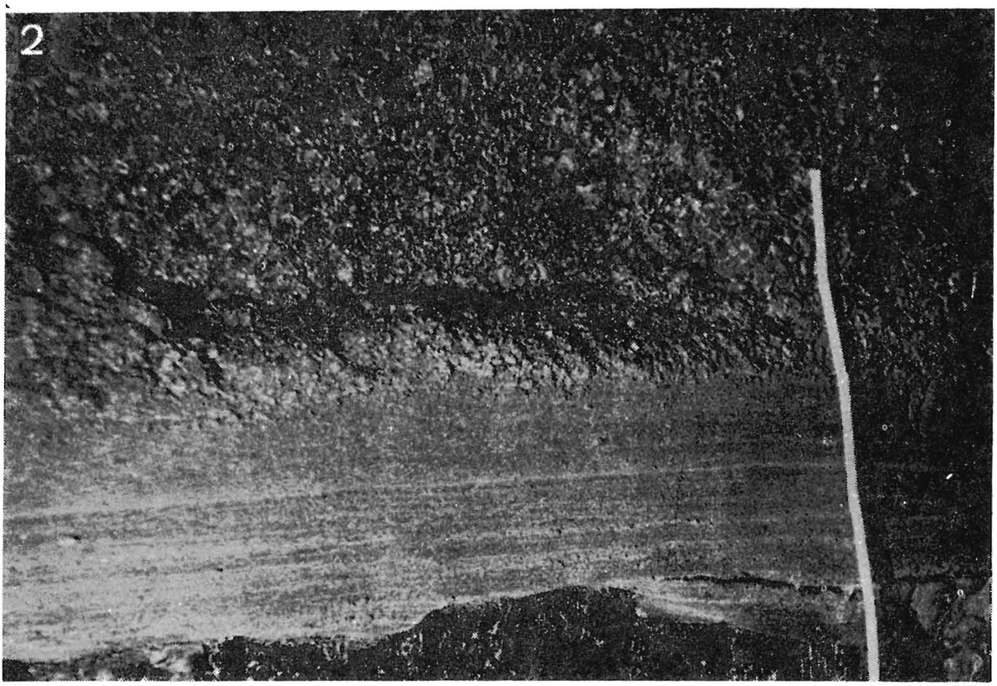




1 — Detail of coarse-grained salt layer within the Salt Breccia Member; Klęczki Chamber (*photo by* K. FEDOROWICZ)

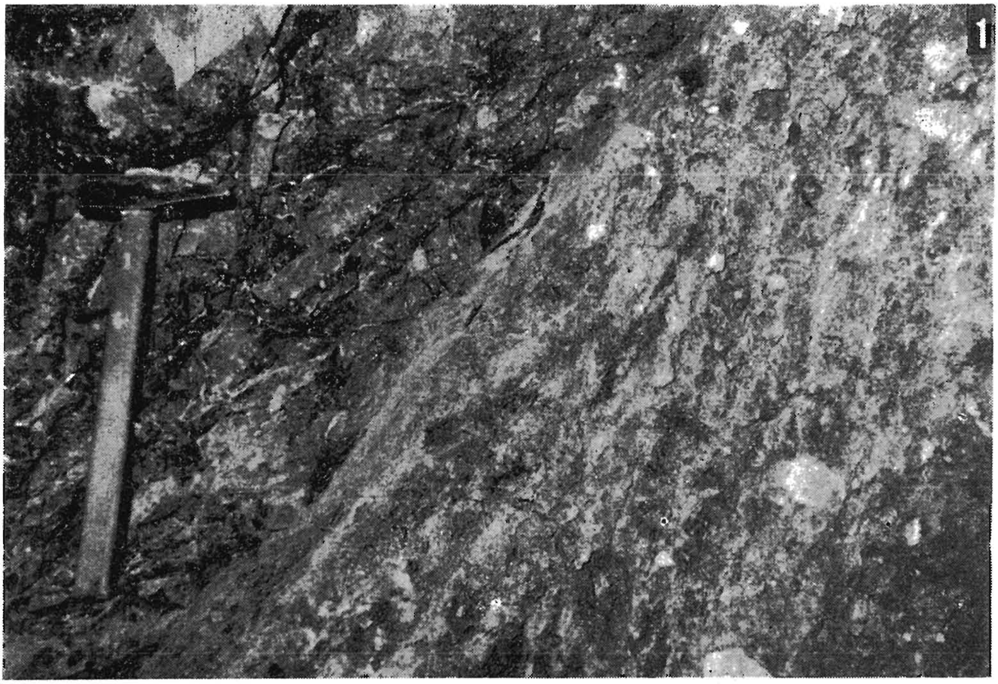
2 — Detail of salt conglomerate within the Salt Breccia Member; Tyrol Gallery (*photo by* K. FEDOROWICZ)

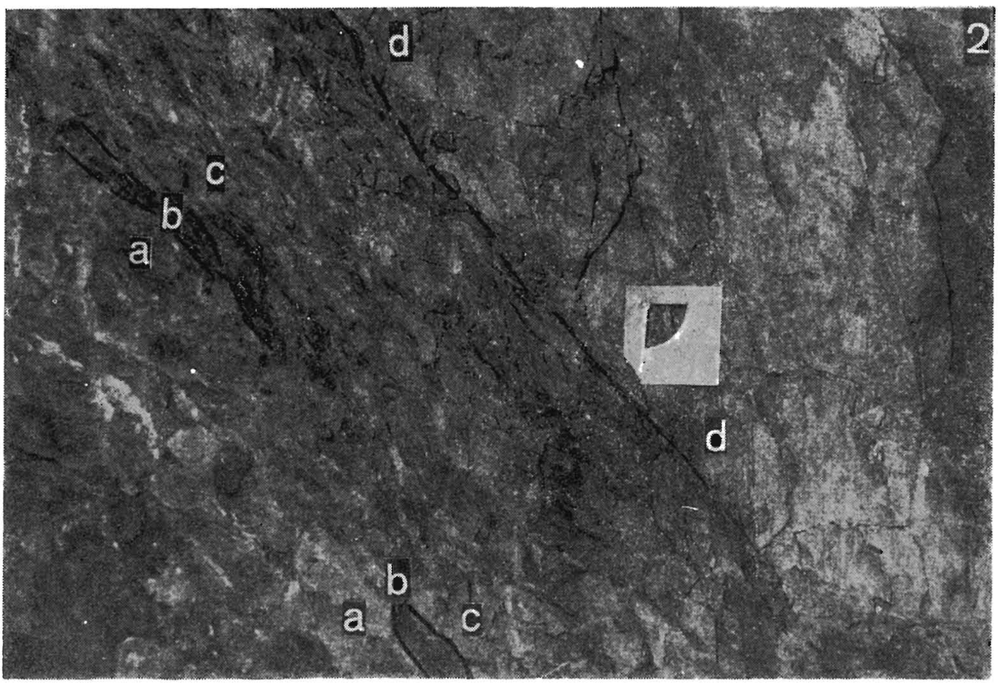




1 — Cross- and paralell-laminated salt passing downwards into conglomerate (block of Miocene clays visible above the hammer); intercalation within the Salt Breccia Member; Klęczki Chamber (*photo by* W. ZALEŃSKI)

2 — Uppermost part of the Klęczki lens built of laminated salt, and a sedimentary contact with the next slump deposit; Klęczki Gallery (*photo by* W. ZALEŃSKI)





1 — Pebbly mudstone with fragments of flysch rocks; Kunegunda Gallery (*photo by* W. ZALEŃSKI)

2 — Slump deposits: **a** — pebbly mudstone, **b** — Albian black shales, **c** — strongly slickensided variegated shales (Upper Cretaceous), **d** — brownish mudstone (Miocene); Kunegunda Gallery (*photo by* W. ZALEŃSKI)