The Upper Permian Zechstein in the Eastern Province of Central Europe

Jozef W. Poborski
Academy of Mining and Metallu
Krakow, Poland

ABSTRACT

The Upper Permian Zechstein Series of central Europe is well recognized in West and East Germany as a typical saltiferous formation laid down in a marine environment. It also extends eastward into Poland and Lithuania.

Since 1956, special studies have been carried on in order to develop an understanding of the Zechstein salt basin in Poland. As a result, a general lithofacies map and cross sections were published in 1967. A greater extent of Zechstein sediments than previously known was shown.

The stratigraphic distinctness of the Zechstein in the eastern province has been proved.

The general pattern of deformation of the evaporites has been illustrated by transverse profiles over Poland's lowland. Halokinetic phenomena are observed.

Development of diapiric salt structures as seen in middle Poland marks the final stage of salt deformation.

The Upper Permian Zechstein Series of central Europe was investigated in Germany a long time ago, and it was there that it was first recognized as a typical salt-bearing formation laid down in a marine environment. This formation, however, is now known to extend farther east into the Polish and Lithuanian (U.S.S.R.) territories.

In Poland much attention has been given to the Zechstein. As a result of concentrated effort which began in 1956, geologists now understand the development of the Zechstein salt basin in eastern Europe. Lithofacies maps and sections illustrate best the evolution of views on the development of the Zechstein basin in Poland. In the constructi of maps and sections, the author has cooperat with the State Geological Survey in Warsaw. F details of basin evolution and facies variations, t reader is referred to Poborski (1960, 1964, 196

The present paper presents, in a generaliz form, the specifications of the Zechstein basin Poland based on current understanding of lith facies relationships. Moreover, the paper has be supplemented with general remarks on tectoni which aid in the better understanding of the spat relationships within this basin.

GENERAL FEATURES OF ZECHSTEIN SEDIMENTATION

The substrata of the Upper Permian Zechstein the eastern province consist only partly of t Lower Permian (i.e., of the Rotliegendes), mair of rocks of older Palaeozoic systems, and partly the Precambrian. The surface over which the s transgressed had been peneplained to a great e tent. At that time, however, there were underwa rock bars, islands and peninsulas. The southe coastline of the Zechstein sea, from the Sudet region in the west to the Holy Cross Mountains the east (Fig. 1), must have been particularly regular and morphologically variegated. The ea ern coastline from the Holy Cross Mounta Peninsula in the south to the Lithuanian Bay far the northeast was uneven too.

The Zechstein sea was shallow and of epicor nental and Mediterranean character. In the e tremely dry and hot climate which prevailed o the vast expanse of the Zechstein sea, intens evaporation of water took place, and the m

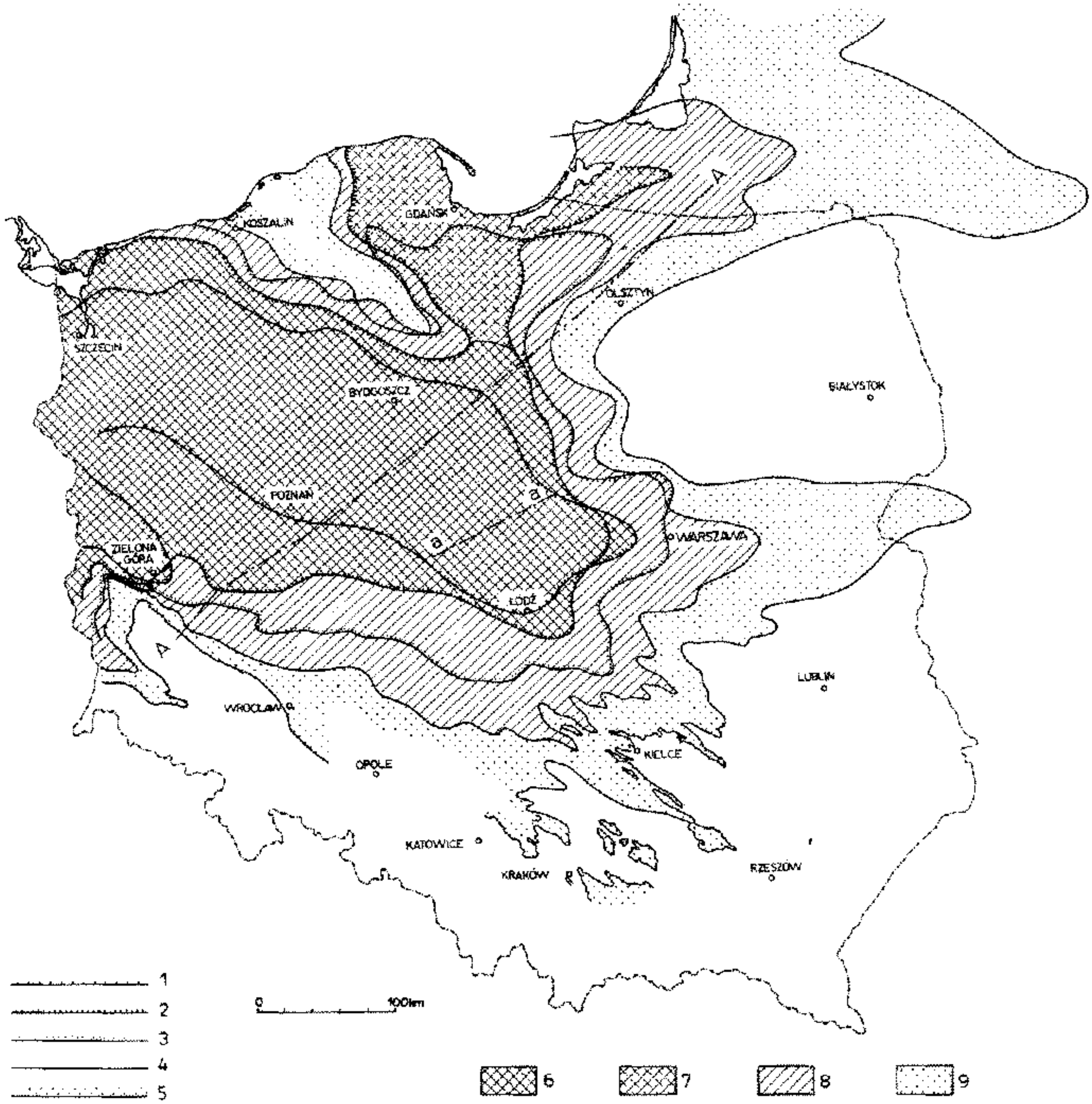

Figure 1. General lithofacies map of the Upper Permian Zechstein Series in Poland and Lithuania (USSR). (1) Limit of the chloride facies with Mg-K salts in the upper division of the Zechstein (Z3 + Z4); (2) Limit of the chloride facies with Mg-K salts in the lower division of the Zechstein (Z1 + Z2); (3) Limit of the chloride facies (without Mg-K salts) in the upper division of the Zechstein (Z3 + Z4); (4) Limit of the chloride facies (without Mg-K salts) in the lower division of the Zechstein (Z1 + Z2); (5) Limit of peripheral facies (sulfate-carbonate, littoral facies); (6 & 7) Chloride (rock salt) facies which is potassium-bearing; (8) Chloride (rock salt) facies without potassium salts; (9) The peripheral, littoral, carbonate-sulphate facies.

advantageous conditions for long continuing sedimentation of evaporites were established. The circumstance favouring the above process was the tendency of the substratum to subside in certain zones, the focal point of subsidence displacing in the course of time. In such a palaeogeographic setting a very thick and widespread sequence of evaporites together with clastic intercalations was deposited. Over a very large area of the eastern province described, its thickness ranges from a few hundred to over 1,700 meters.

REMARKS ON STRATIGRAPHY

The stratigraphic division of the Zechstein used at present is based on lithology. The basis of the division was a cyclic recurrence in the sedimentation process of a distinct salt-bearing sequence. The Zechstein may be easily divided into four cyclothems. Thus, it seemed quite purposeful and logical to introduce a new division of the Zechstein into four stages corresponding to the cyclothems mentioned. A suggestion of the German geologists was accepted in that respect (G. Richter-Bernburg, 1955). Each particular stage of the Zechstein was denoted as follows: Z1, Z2, Z3 and Z4.

The lithologic characteristics of the key beds for the individual stages of the Zechstein are adequately described in both the German and Polish literature (Poborski, 1960, 1964). It is worthy of note that the most reliable key bed in the area occupied by the salt basin is the "grey salt clay" (Grauer Salzton) with a thick bed of "principal anhydrite" (Hauptanhydrit) overlying it. These units mark the base of stage Z3 (the cyclothem of "younger salts").

SPATIAL LITHOFACIES RELATIONSHIPS

A general picture of lithofacies relationships was outlined on the first maps of the Zechstein basin. These first general lithofacies maps, without showing a division of the Zechstein into stages Z1, Z2, Z3 and Z4, did however demonstrate the regularity of the facies variations quite typical for numerous salt basins in the world. Namely, in the central part of the basin evaporites of a higher order, i.e., more soluble salts, are deposited. As these salts are traced towards the periphery of the basin they grade into evaporites of a lower order (less soluble) and these in turn into clastic littoral sediments. At the same time a concentric arrangement of the facies fields in the basin as a whole is observed.

The latest lithofacies map as of this writing were constructed in 1967 at the original scale 1:500,000. Figure 1 presents a considerably g eralized sketch of the original.

In comparison with the earlier editions, the map presents a more detailed picture of the Z stein basin border on both the south and eas border of contemporary Zechstein sediments. the same time, the dismembering of the basir the southeast direction and its extension under Carpathian overthrust is evident. This new pre tation results from a better understanding of li facies relationships.

The salt-bearing Zechstein was mainly depos in a marine environment. However based on s mentological studies, portions of this series se to have been deposited in a lagoonal-contine environment. Thus, the Zechstein salt is litho ically associated with two contrasting envi ments of deposition: (1) marine, (2) lagoonal-continental. The marine salt-bea units consist almost entirely of evaporites wl were deposited in isolated and stagnant sea ba fed by the inflow of the ocean water. On the o hand, the continental salt-bearing units were posited in drying up, depression centres on continent which were receptacles of salt waters the same time, under desert conditions, cla material migrated to these receptacles.

Each of the salt-bearing units mentioned refl its specific sedimentation conditions. Thus, in typical "marine" unit rock salt is freque accompanied by thick beds of anhydrite with bonate layers beneath. Rock salt itself is usu colourless, white, or grey. Rock salt in the "co nental" units is usually coloured with iron ox and occurs within a prevailing mass of lu (mainly clays) which are most frequently re colour. The most characteristic rocks are c mixed clay-salt type, viz. "zubers" (Gen Haselgebirge).

The facies changes in both units are quite r lar, but there is a slight difference in the cha teristic occurrence of each of them.

The spatial lithofacies relationships are the lowing: In the cross section of the basin (A-A), "continental" sediments overlap in a way, "marine" sequence (Fig. 2). Their borders are allel to or discordant with chronostratigra lines, i.e., the stage borders. Moreover, it has b determined quite recently on the southern ma of the salt basin proper that the nonsaline " rine" units grade horizontally into nonsaline "c tinental" facies.

The generalized map of the Zechstein basin (1) presents an integrated lithofacies picture

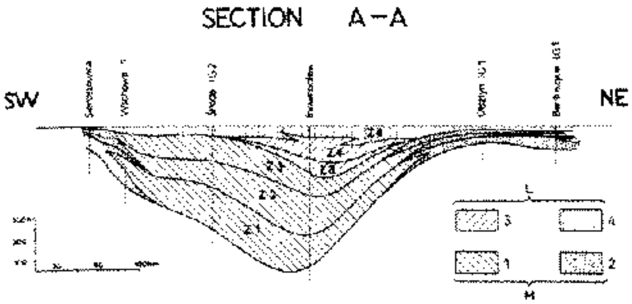

Figure 2. Lithofacies section A-A across the Zechstein basin in Poland.
M—Marine megafacies: (1) Chloride facies; (2) Peripheral facies (sulphate-carbonate, littoral facies).
L—Lagoonal-continental megafacies: (3) Chloride facies; (4) Facies of associated lutites (pelites and aleurites).

both salt-bearing sequences. The area of the basin is divided here into three fields of the following facies:

(1) Chloride (rock salt) facies which is potassium-bearing (6, 7).

(2) Chloride (rock salt) facies without potassium salts (8).

(3) The peripheral, littoral, carbonate-sulphate facies (9).

Within the borders of the salt basin proper (the area underlain by chloride facies) the Zechstein is cartographically differentiated into two parts: the lower (Z1 + Z2) and the upper (Z3 + Z4). This cannot be done in the peripheral zone.

In the general picture of the basin, a concentric distribution of the facies fields in relation to the central potassium-bearing one is evident. Quite characteristic however, is the branching out of the potassium-bearing field under Gdansk Bay.

CERTAIN PALAEOGEOGRAPHIC FEATURES

The sedimentation of evaporites was quite sensitive to the changes in the palaeogeography of the basin (distance from the coast, basin depth, bottom subsidence, etc,). Facies changes, indicated on the map (Fig. 1), reflect well the palaeogeographic conditions.

In the central portion of the basin, the zone of the greatest evaporite thickness lies in the geological region known as the central Polish anticlinorium. This is a wide zone with a northwest-southeast trend, situated along the edge of the east European crystalline platform. It is known as the zone of the strongest epeirogenic subsidence, especially during deposition of Zechstein Z3 and Z4.

In the northern part of the country (Fig. 1), the area underlain by chloride facies is divided by a wedge of littoral facies widening toward the northwest, i.e., toward the Baltic. Along the axis of this wedge (Koszalin-Tuchola), between Early and Late Permian time there must have existed an archipelago built of old Palaeozoic rocks (Silurian, Devonian, Carboniferous) which was degraded during deposition of Zechstein Z1 and Z2.

The archipelago Koszalin—Tuchola was, up to a certain point, a barrier which dismembered the central portion of the basin, and separated the potassium-bearing Gdansk Bay region from the basin proper.

On the southern margin of the salt basin proper, particularly in the Krakow region, the landscape must have been much varied. The degraded ridges of Variscides (NW-SE trend) built of the carbonate formations of the Devonian and Carboniferous were still rising. The Zechstein sea advanced upon the land between the rows of monadnocks, a fiord-like topography resulting. This explains why breccias and conglomerates are the most characteristic sediments there.

With an understanding of the palaeogeographic conditions at the time of sedimentation in the southern marginal area of the salt basin, former stratigraphic conceptions can be revised. We are now inclined to assign a Zechstein age to some clastic sediments included formerly in the Rotliegendes (Lower Permian) or in the Buntsandstein (Trias).

Bands of sulphate, carbonate and littoral facies may be identified in the peripheral zone along the east coast of the basin (Fig. 1). Strongly developed organic reef limestones occur in the band of carbonate facies. They were barrier reefs, previously recognized in some sections of the coastline of the Zechstein sea, e.g., in the Gera region in Thuringia (East Germany). A certain analogy to the reef rocks in the periphery of the Permian salt basin in West Texas and southeast New Mexico (King, 1948) can be noticed.

DISTINCTNESS OF THE ZECHSTEIN PROFILE

In the eastern province, the Zechstein section is most completely developed in the zone of the central Polish anticlinorium and in the adjacent synclinoria. In comparison with the full profile of the western province (North German Lowland) a marked distinction in the lithostratigraphic development of the stages Z3 and Z4 is observed. Starting in about the middle of the Zechstein Z3 sequence and extending up to the Triassic "variegated sandstones" (Buntsandstein), sedimentation took place in the "continental" environment. Fine detritus from the east shore drifted into the drying salt pan. Under these circumstances halitic lutites ("zubers") were formed.

By the time of termination of deposition of the Zechstein Z3, the rate of accumulation of the terrigeneous material exceeded the rate of subsidence. The beginning of deposition of Zechstein Z4 was characterized by desication of subaerially exposed salt muds ("continental" stage). Thus, in the stratigraphic column, a "red salty clay" (Roter Salzton) is characteristic. In the western province this me ber is considered the basal unit in the stage : "Zubers" are characteristic of upper parts of b stages Z3 and Z4.

In the potassium-bearing area of Gdansk B the profile of the Zechstein is still more vari Only the lower part of stage Z1 is similar to that the western province.

TECTONICS

In the central and largest area of the ba underlain by the chloride facies, the general de to the top of the Zechstein is about a few thous metres (2,000-4,000). In certain regions of cen Poland the depth is still greater, in some pla exceeding 6,000 metres (Figs. 3, 4). In the t

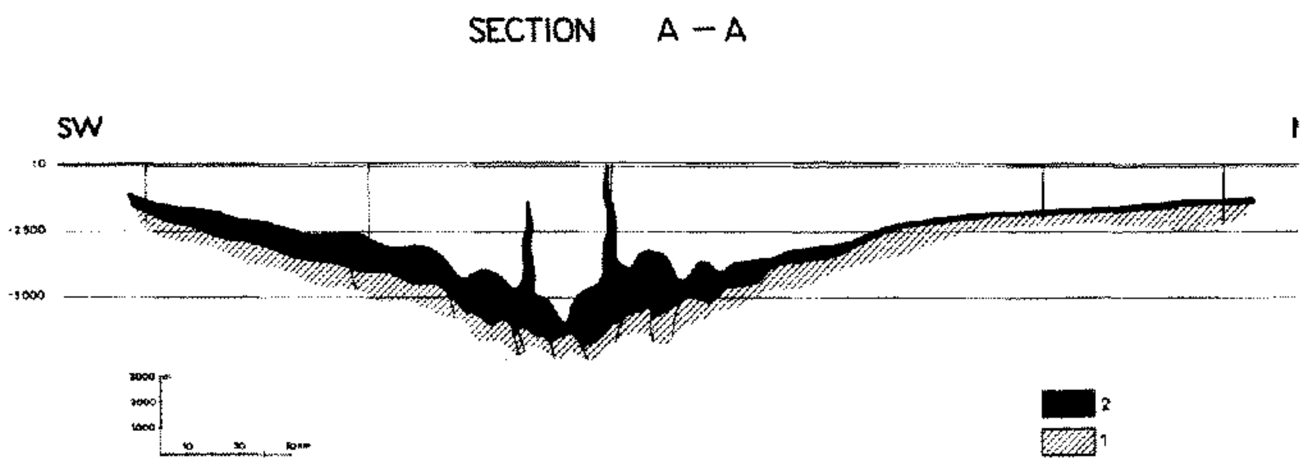

Figure 3. Profile through the Zechstein Series along A-A (Fig. 1). (1) Substratum of the Zechstein; (2) Zechstein Series.

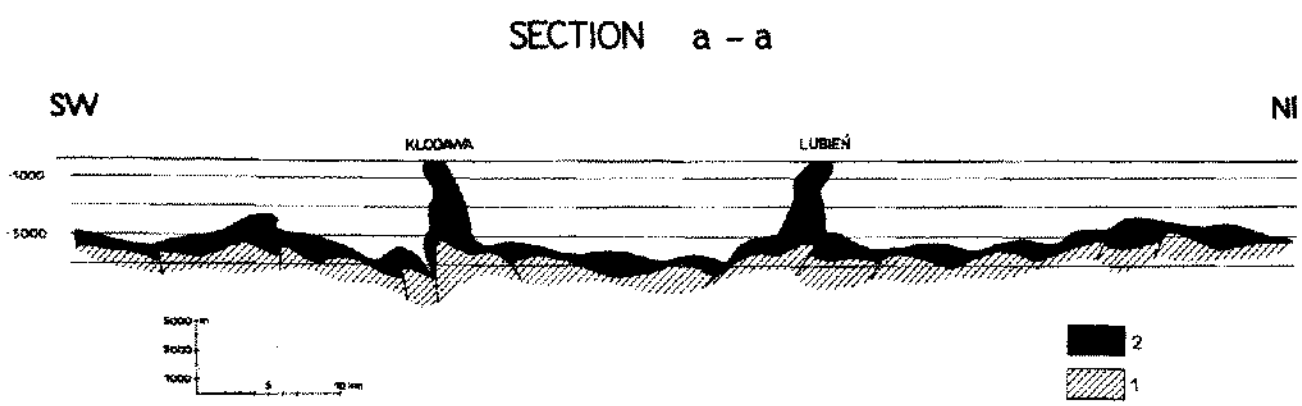

Figure 4. Salt domes along cross-section a-a (Fig. 1). (1) Substratum of the Zechstein; (2) Zechstein Series.

eccentric regions of the chloride facies only, it is less than 1,000 metres, viz. in a sector of the Sudeten foreland and on the Leba elevation on the Baltic Sea (the western part of the potassium-bearing Gdansk Bay).

The carbonate-littoral facies of the Zechstein forms outcrops both in the Sudeten and Holy Cross Mountains (Fig. 1).

The Zechstein salt-bearing series under the overburden of the Mesozoic systems played a special role in the tectonic processess in the lowland of central Europe. Owing to the relative plasticity of salt, this series absorbed movements of the deeper substratum in relation to the whole Mesozoic and Caenozoic cover. In this respect, the halokinesis theory is valid.

Nearly all the area of the salt basin proper was subject to halokinetic disturbances. This is frequently overlooked in the drilling profiles. These disturbances were the strongest in the central portion of the basin, where halokinetic phenomena developed. Diapiric structures are the culminant symptom of the halokinesis. Central and northwest Poland is the territory of diapiric structures. In the central part of the country more than ten such structures (salt domes) are recognized at present. Four of them are exploited for salt (Wapno, Inowroclaw, Gora, Klodawa).

Figure 4 presents the cross section (SW-NE) of the central Polish anticlinorium in the Kujawy section (Kujawy anticlinorium). Two salt domes (Klodawa and Lubien) are visible in this cross section.

In Poland much attention is concentrated on the internal structure of the salt domes, largely as a result of the underground geological mapping in the salt mines.

Figure 5 shows a cross section of the salt dome at Klodawa, throughout its whole height. This reconstruction was undertaken to explain the genesis of gaseous and liquid hydrocarbons which are present in salt mines.

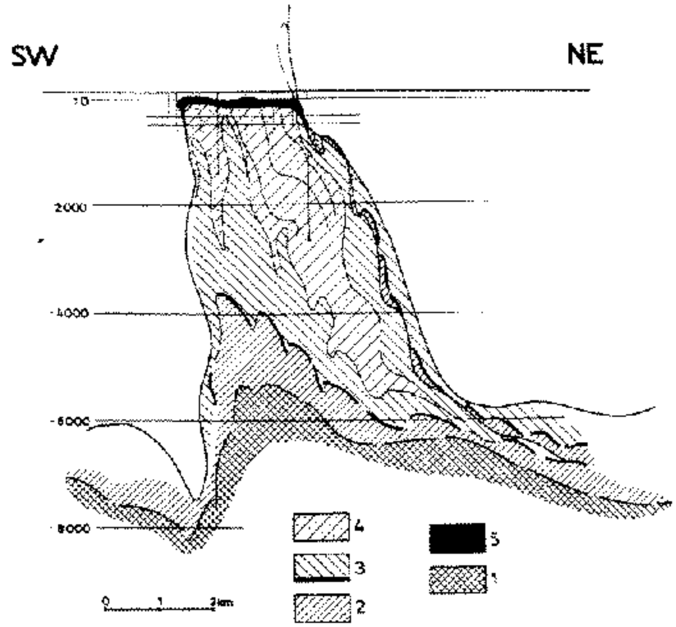

Figure 5. Inner structure of the salt dome of Klodawa. (1) Substratum of the Zechstein; (2) Zechstein Z1; (3) Zechstein Z2 (including the "principal dolomite"); (4) Zechstein Z3 + Z4; (5) Gypsum caprock.

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