AAPG Search and Discovery Article #90049©2000 AAPG/EAGE International Research Conference, El Paso, Texas, October 1-5, 2000 (2005)

Geological Analysis of the Zechstein Limestone Formations (Ca1) in Western Poland

PIKULSKI, LESZEK, and TADEUSZ WOLNOWSKI, Polish Oil & Gas Company, Geological Bureau GEONAFTA, Warsaw, Poland

The Upper Permian Zechstein Limestone (Ca1) has been the subject of the search for oil in Poland for a number of years. This formation has been found to be productive in several gas fields, e.g. Bogdaj-Uciechow, Henrykowice, Radziadz, Borzecin. In most fields, the Zechstein Limestone constitutes the gas-bearing horizon together with the Upper Rotliegendes sandstones. Drilling started in 1996 in the central part of the Wolsztyn Uplift. This drilling led to the discovery of Koscian gas field in the Zechstein Limestone (Ca1). The resources in this field are estimated to be over 10 billion m^3. Other wells drilled in 1998 (Bonikowo-1, Krzywin-1, Biatcz-1, Wielichowo-1) and located about 6 kilometers (about 3.7 miles) from the northwestern boundary of this gas field, demonstrate the existence of hydrocarbon fields in the Zechstein Limestone.

The purpose of this paper is to present the Ca1 depositional conditions within the Wolsztyn Uplift area and emphasize the potential of reef facies in this area. The typical feature of this kind of sedimentation pattern is increased reservoir thickness and good reservoir properties.

Development of Cyclothem PZ1 Sedimentation—The transgression of the Zechstein Sea was rapid. Undoubtedly, the oldest Zechstein deposits, found locally only, is the Zechstein Conglomerate. The Copper Shale (T1), located above it, is a chronostratigraphic horizon (P. A. Zeigler, 1990). It is typical in western Poland where the Copper Shale is found that deeper water environments are not evident. They are not present in the Wolsztyn horizon nor in any places in the peripheral parts of the basin. In some areas in western Poland, a gradual change of Copper Shale into Zechstein Limestone (Ca1) can be seen. This is the result of better water circulation and a slower subsidence rate which improved environmental conditions encouraging the rapid development of fauna. Transgression of the sea reached its maximum range at that time and created a basin with a diversified coastline. The Zechstein Limestone Sea was a shallow basin (maximum depth up to 100 meters (328.1 feet) with typical marine salinity and a rich fauna. The thickness of Zechstein Limestone varies from tens of centimeters to over 100 meters (328.1 feet). During Zechstein Limestone deposition, sea level was lowered three times and the third lowering took place at the end of Zechstein Limestone deposition (T. M. Peryt, 1984). The return to deep-water conditions was very rapid. Two sedimentation cycles, the first and third, are clearly visible (J. Paul, 1991), whereas the second sedimentation cycle is not. In the last phase of a sedimentation cycle, a remarkable lowering of the water level in the basin occurred. As a result, not only carbonate platforms, but also significant areas of the basin plain were exposed; carbonate sediments thereby underwent intensive diagenetic changes (T. M. Peryt, 1984).

Another evaporation stage in the development of the PZI basin started with a new transgression of the sea. In the extremely dry climate of the Lower Anhydrite (Ald), sedimentation took place very quickly. In the lower parts of the profile, it is represented by extremely shallow water knobby and mosaic anhydrites changing upwards into more deepwater irregular laminated and stratified anhydrites. The anhydrite thickness varies from 12 to over 300 meters (39.4 to 984.2 feet) in shallow water areas and 30 to 70 meters (98.4 to 229.7 feet) in the center of the basin.

The most important effect of anhydrite sedimentation was the differentiation of the bottom morphology of the basin. Because of rapid sulfate sedimentation, minor Zechstein Limestone differences in morphology grew larger as a result of rapid subsidence. In this part of the basin, the sedimentation of the Oldest Halite (Na1) took place. Its thickness exceeds over 100 meters (328.1 feet).

Another Upper Permian Sea transgression of the sea halted the accumulation of the Oldest Halite and brought about deposition of sulfate sediments of the Upper Anhydrite (Alg). In the deeper part of the basin, there were deeper water conditions, and the Upper Anhydrite thickness here is about 50 meters (164 feet). The anhydrite itself consists mainly of laminated anhydrite. In the area of transition from deep to shallow water, Werra anhydrite (Ald+g) platforms can be seen. Their thickness exceeds 300 meters (984.2 feet). In the final stage of the cyclothem PZ1 basin development, the majority of sulfate platforms were exposed and even partly eroded (R. Wagner, 1994).

Another stage in the evaporate development of the basin was the Main Dolomite (Ca2) sedimentation. That problem has been thoroughly discussed in numerous papers and by the authors presentation at 61st EAGE Conference & Technical Exhibition in Helsinki, 1999.

Facies Variation of Zechstein Limestone—The typical features of Zechstein Limestone are significant variability of formation thickness and facies, which influenced the unstable chemical composition and fauna that became adapted to these conditions. The variability of Zechstein Limestone was caused not only by background morphology, subsidence, sedimentation rate, ecological conditions and chemical processes, but also intensity and variety of diagenetic phenomena. In the Zechstein Limestone Sea, three main paleogeographical areas have been distinguished.

Basin Plain—This is found in areas of the central basin. The average Zechstein Limestone thickness is from 1 to 5 meters (3.2 to 16.4 feet). The profile is exceptionally diversified which was caused by a significant fluctuation of sea level during deposition. The typical profile consists of carbonate mud in the basal part, whereas in the upper part, oncolites and stromatolites can be found. Within the plain, stromatolite-bryozoan reefs may occur, whose thickness is up to 80 meters (262.5 feet). These reefs develop on the uplifted blocks of pre-Zechstein basement.

Carbonate Platform Slope—This is formed as a result of the break between the outside platform edge and the basin plain. The typical features of this area are the redeposition of carbonate material from the platform and, because of the steep slope, mass movement of sediment is found (gravity flows). This can be seen in granular dominate sediment mixed with carbonate mud brecciated deposits which appear to be the result of gravitational flows. The Zechstein Limestone sediment thickness in this area varies from 10 to 30 meters (32.8 to 98.4 feet).

Carbonate Platform—This is characterized by intensive microfacies diversification in shallow and extremely shallow water carbonate environments. Within the carbonate platform the pre-reef, reef and lagoon zones can be distinguished. In the shallow water environments, oolitic to oncolitic sediments with stromatolite-bryozoan bioherms and recrystallized algal laminate occur. These sediments have oncolitic grainstones (intraclasts and oolites) with anhydrite impregnated grainstones that are found with clear vadose modification, such as cement and vadose coatings. A rich fauna is represented by numerous species of brachiopods, mollusks, and bryozoans. Gastropods, echinoderms and worms are fewer. Corals and crinoids are rare. In local depressions, carbonate muds accumulated and grainy elements were deposited. The Zechstein Limestone reaches maximum thickness in this area and is characterized by very good reservoir properties.

<u>Structural and Topographic Characteristics of the Region</u>—In the center of the study area, the Wolsztyn Uplift massif is located. It was formed as part of the Variscan orogeny where Lower Carboniferous rocks are folded with older basement. Generally, fold axes found on the Wolsztyn Uplift are aligned in a NW-SE direction, which determines the spatial development of the area.

Volcanic rocks are formed along the deep tectonic fractures. As a result, paleostructural elevations of about 100 meters (328.1 feet) appear with volcanics or Carboniferous rocks at the higher elevations. A few meters of thick tuff, tuffite and volcanic breccia or a series of sandstones and conglomerates suggest the proximity of the Rotliegendes sediments. The northeast boundary of the Wolsztyn Uplift is characterized by numerous erosional peninsulas and bays.

Within the Wolsztyn Uplift, the base of the Zechstein is found at various structural elevations with dips locally towards the northwest. The difference in the present structural configuration from Pogorzela to Marwice to Sciechow amounts to almost 1900 meters (6233.5 feet). Such a difference could not have existed at the initial stage of Zechstein Limestone deposition. The shallow Zechstein Limestone has been found on post-Variscan elevations in the area of Pogorzela. The stratal elevations are at depths of 1600 to 1900 meters (5249.3 to 6233.5 feet), as evidenced by the following wells: Pogorzela-1 (1640 meters (5380.5 feet)); Pogorzela-2 (1619.5 meters (5313.3 feet); and Pogorzela-4 (1877 meters (6158.1 feet)). Northwest along the Wolsztyn Uplift a large, relatively flat area called the Katarzynin-Koscian-Wielichowo area can be seen. Here the base of pre-Zechstein or top of the Carboniferous has been drilled at depths of 2150 to 2350 meters (7053.7 to 7709.9 feet). Wells (with elevations) such as Katarzynin-2 (2290 meters (7513 feet); Koscian-14 (2189 meters (7181.7 feet); Koscian-9 (2157.8 meters (7079.3 feet); and Wielichowo-1 (2342 meters (7683.6 feet) are located in this area. In the area of Paproc-Zbaszynek, these strata have been found at depths of 2400 to 2500 meters (7874 to 8202 feet). Wells located here include Paproc-23 (2454.5 meters (8052.7 feet); and Zbaszynek-5 (2471.6 meters (8108.9 feet)). In the area of Gorzow, these strata occur at a depth of 3000 meters (9842.4 feet) in the Wlkkp-2 to Miedzyrzecz-1A to Bolewice-1 wells. Wells located here include Miedzyrzecz-1A (3090 meters (10137.7 feet)); and Miedzyrzecz-2 (2979.5 meters (9775.1 feet)). North of the area of Krobielewko and Miedzychod, wells Krobielewko-2 (3402 meters (11161.3 feet)); Miedzychod-2 (3450 meters (11318.8 feet)); Miedzychod-3 (3466 meters (11371.3 feet)); and Sciechow-1 (3492 meters (11456.6 feet)) penetrate these strata at a depth of 3400 meters (11154.7 feet). At Chrzypsko-2 (3612.5 meters (11851.9 feet)) a well of deeper stratal penetration occurs. These stratal elevation figures show that we are dealing with a local deepening of the stratigraphic section towards the northwest which is towards the center of Lower Permian Basin. In this paper, we have discussed the paleomorphological analysis of the region and have reconstructed the initial morphological conditions that existed just after the transgression of the Zechstein Sea. This analysis is crucial to the successful search for hydrocarbons in the Zechstein Limestone (Ca1) and the Main Dolomite (Ca2).

<u>References</u>

Paul, J., 1991, Zechstein carbonates-marine episodes of a hyperhaline sea, Zbl. Geol. Palacont. Teil I, H. 4, 1029-1045.

Peryt, T. M., 1984, Sedimentation and early diagenesis of the Zechstein Limestone in Western Poland, Pr. Inst. Geol., 109, 1-80, Warszawa.

Pikulski, L., Wolnowski, T., 1999, The geological analysis of the Main Dolomite formations (Ca2) in the Western Poland, 61st EAGE Conference & Technical Exhibition, Helsinki.

Wagner, R., 1994, Stratigraphy and evolution of the Zechstein basin in the Polish Lowland, Pr. Inst. Geol., 1-75, Warszawa.

Ziegler, P. A., 1990, Geological Atlas of Western and Central Europe, Shell Internationale Petroleum Maatschappij, B. V.

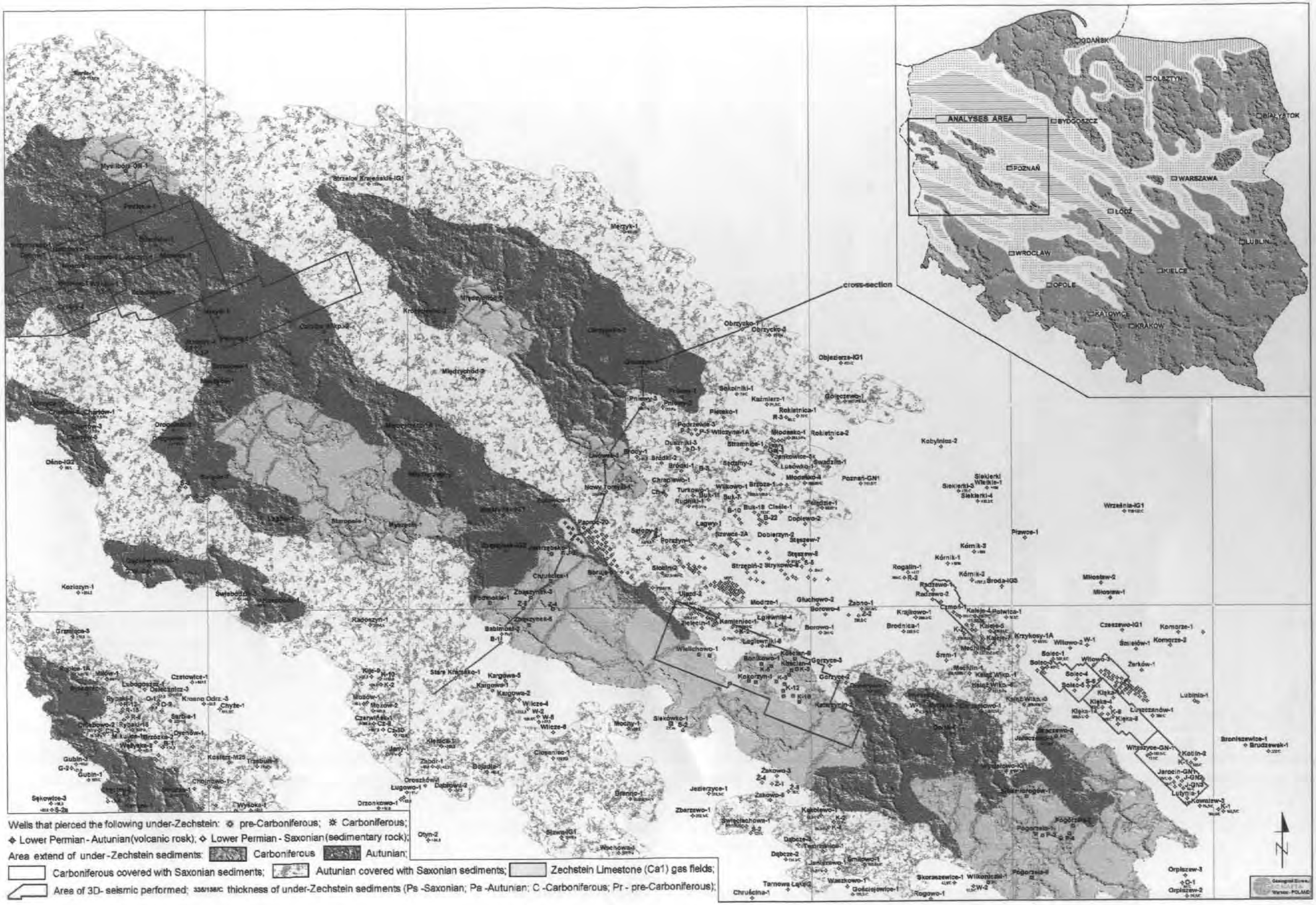

Fig. 1. Regional setting of the Zechstein Limestone gas fields and extent of the Wolsztyn Uplift (L. Pikulski, 1999)