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STUDY IN THE DEVELOPMENT OF MAIN DOLOMITE (Ca2) IN WESTERN POLAND IN THE ASPECT OF HYDROCARBONS SEARCH

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SUMMARY
The area in question has been intensively analysed in geological and seismic terms. It is situated on two separate tectonic units that are defined and limited in different ways in literature. It may be stated that, in geological terms, the area comprises the most south-east protruding part of Szczecin Synclinorium. At the end of it a regional strike of tectonic displacement and layers of permian – mezozoic elevations connected with it and called Gorzow Region are to be found. The drilling work in 1990 proved the existence of string of isolated elevations within the deep marine, barrier and lagoon zones Zechstein Main Dolomite. Moreover, the presence of industrial oil and gas accumulations was confirmed. The wells were drilled among others, in the following fields: Barnowko – Mostno – Buszewo (B-M-B) Gorzyca, Miedzychod (oil & gas fields), Rozansko, Krobielewko (gas fields), Jeniniec, Sulecin, Namyslin, Lubiszyn, Dzieduszyce, Chrzypsko (oil fields) and Zielin, Stanowice (gas – condensate fields). The presence of hydrocarbons in each well makes the area highly prospective. In this presentation the main geological factors causing such high perspective will be discussed.

Sedimentation conditions
The first cyclothem formation (PZ1), varies from about 110,0 meters *[360 feet]* in the basin open marine environment to over 300,0 meters *[984,2 feet]* the Zechstein paleoelevations which spreads along the northern edge of Wolsztyn Uplift. This results in considerable depth variations of the reservoir at the end of PZ1 cyclothem. The Main Dolomite (Ca2) sedimentation took place mainly in the area of the Gorzow Region where a carbonate platform is attached to the main land. Four sedimentation zones differing in facies are found:

DEEP MARINE ZONE. This part of the Main Dolomite is developed as dark grey limestone, highly clayey and sometimes slightly dolomite. The zone can be described as a clayey mudstone facies. This Main Dolomite reaches the thickness of 7 meters *[23,0 feet]* near elevated highs and in the Zechstein basin it turns into stinking schist the thickness of which is 3 to 5 meters *[9,9 to 16,5 feet]*.

FRONT BARRIER ZONE. This zone is found at the foot of a sulphate platform cyclothem PZ1 slope. It has been best recognized by wells in the region of Sulecin, Chartowo and Lubiszyn. The Main Dolomite located on the sulphate platform slope has been seen by Lubiszyn-2 and Lubiszyn-3k wells. This carbonate level is characterized by alternating limestones and dolomites with dolomites dominating. They are usually dark grey dolomites of the grainstone or packstone type. The dolomite Ca2 thickness is in zone varies from 5 to 15 meters *[16,5 to 49,5 feet]*. The typical feature of front barrier dolomites is that they have a form of dolomitic breccia such as conglomeratic to brecciated and oolitic to onkolitic dolomites. This breccia is cemented with anhydrite and salt, which makes the reservoir properties unfavourable. Structurally, the breccia may be recognized as dolomite sediment flows from a barrier zone.

BARRIER ZONE. Forms a border between the open sea and the lagoon. This zone has been well examined from numerous wells. Dolomite thickness from this zone varies from 20 to 100 meters *[66 to 330 feet]*. The Main Dolomite usually has the form of dolomitized oolitic grainstone. Microscope analysis allows us to distinguish three levels of different deposition conditions within the barrier and lagoon zones. The levels may by correlated in the entire area of the Gorzow Region. The detailed description of the forms can be found in further part of the paper.

LAGOON ZONE. This zone is usually separated form the sea by a carbonate barrier. Climate conditions and the type of connection with the open sea created various degrees of salinity. This, salinity influenced the character of organisms living

in the lagoon. The typical feature of tightly isolated lagoons is a distinct diagenesis, almost simultaneous with sedimentation which leads to an early dolomitization. The upper part of the Main Dolomite profile drilled in the Sciechow-1 corresponds with these conditions. Within the lagoons shallow-water structures called internal barriers are formed.

The development of the Main Dolomite barrier zone lithofacies.
The analysis of the facies development of the Main Dolomite has been conducted on the basis of macroscopic and microscopic observations. Some previous microscope examinations were useful. The sedimentation conditions of cyclothem PZ1 described above influenced the development of the Main Dolomite. In studied area mainly represented barrier zones are the following facies zones can be distinguished:

LEVEL A. Is usually located in the lowest part of Ca2. It is represented by crystalline dolomites. Highly developed processes of recrystallisation, dissolution and anhydritization obliterate primary structural and textural features of this level. Occasionally onkolitic and intraclastic relics can be found. In the lowest part of this level there are thin anhydrite stringers, which show there occurred a very slow change in sedimentation conditions. In those layers, microstyolites containing bitumen can be found. The amount of primary anhydrite is also considerable.

LEVEL B. This is located in the middle part of Ca2. It is formed as knobby-oncolitic grainstones, organodetrital grainstones, knobby-oncolitic mudstones which are slightly impregnated with anhydrite. Oncolitic grainstones with numerous intraclasts can also be found. Primary structural and textural features often become obliterated by aggradational neomorphism, dissolution and secondary cementing, but to a lesser extent than in level C. Sparite and sulphate cement comprise only an insignificant part of intergranular space volume. Numerous cavern-like interstices and crevices are usually filled with secondary anhydrite.

LEVEL C. This is located in the upper part of Ca2. It is represented; (1) recrystallised organodetrital oolitic to intraclast grainstones with a considerable amount of vadose cement; (2) oolitic to peloids packstones with highly visible vadose cements; (3) algal and laminar biolithit; (4) biolaminoids with abundant anhydrite impregnation. Dissolution of carbonates and secondary sulphate cements are common. The typical feature of this zone is, a very strong influence of vadose phenomena such as cements and vadose coats, vadoids which obliterate the primary structural and textures of the rock.

Reservoir properties
The typical feature of the Main Dolomite forms are significant changes of reservoir properties, both horizontal and vertical. The changes are discernible even within a single field. The pores originally constituting intergranular space of carbonate Ca2 forms are seldom preserved. In these rocks the dominating feature is porosity resulting from dissolving of carbonate grains; the porosities form irregular interstices reminding caverns rather than open slits. Advanced secondary cementation and filling of primary pores caused by secondary anhydrite recrystallisation led to the loss of initially good reservoir properties (as the primary carbonate sands porosity may indicate).

The absence of early cements in grainstones indicates that they did not undergo vadose processes; for that reason primary intergranular porosity could be preserved. The layers that underwent secondary cementation are characterised by low permeability and constitute a physical barrier to lateral hydrocarbons migration. The conditions allowing to preserve primary porosity can be found at grainstone rather than at mudstone and packstone levels. Reservoir properties of the Main Dolomite forms surrounding barrier zones are characterized by their components. Good sealing of the Main Dolomite forms by the superincumbent levels (Basic Anhydrite - A2 and Older Halite - Na2) largely limited horizontal hydrocarbon migration. As a result, accumulated hydrocarbons remained in potential lithological – structural traps existing within the carbonate Ca2 barrier. That state lasted until the Cimmerian rebuilding, when their sinking took place.

The development of Main Dolomite (Ca2) carbonate platform
The coating of volcanic rocks (Lower Rotliegendes) appearing along deep tectonic fractures in the areas of active dislocations started to crack and erode quickly. This is how paleoelevations 100 m *[330 feet]* high originated. Their centers are carbon or volcanic rocks of the higher elevation. A relationship among the range of under-Zechstein

paleoelevations, the range of sulphate Werra platforms and the run of barrier zone in Main Dolomite can be noticed. The relationship seems to be proved by sedimentary conditions. Barrier forms of Main Dolomite developed on anhydrite Werra platforms which had their sedimental base on under-Zechstein paleoelevations.

After the settlement of sulphate platform PZ1 formations there occurred a change in sedimentation conditions. Initially carbonate-sulphate formations appeared. The characteristic feature here is a 3 meters thick anhydrite – carbonate insert in the top of the Upper Anhydrite (A1g). The moment of sedimentation change can be traced thanks to the Main Dolomite transition zone the thickness of which is up to 5 meters *[16,5 feet]* and which is typical of the whole Zechstein basin. It is the beginning of the processes connected with creating of the carbonate platform Ca2. Level A is usually characterized by poor reservoir qualities.

After the deposition conditions within the area of the sulphate platform standarized, carbonate structures could easily form, as they are typical of high-energy water sedimentation (level B). That level is characterized by good and sometimes very good reservoir properties, which is caused by the existence of grainstone facies with little anhydrite. Intensive growth of carbonate barriers resulted in variety of morphological plan: there are such forms as ring, ribbon and semicircular barriers. They are to be found within the carbonate Ca2 platform, their thickness varied. In the vicinity of barrier ridges the thickness is the highest, from 20 to 30 meters *[66 to 99 feet]* (sometimes even 50 meters *[165 feet]*), whereas behind the barriers it goes down to 10 – 20 meters *[33 to 66 feet]*. The system of flowing or overflowing canals providing fresh water and organic material has relatively poor documentary evidence.

The lowering of wave base made the top parts of big barrier form emerge, they became subjected to the influence of meteoric water; this led to the development of structures in level C. Strong influence of aggradational neomorphizm makes it difficult to recognize primary structural features of the rock. Moreover, vadose carbonate – anhydrite cement filling pores and caverns reduce reservoir properties considerably.

The transition form carbonate Ca2 to sulphate sedimentation is gradual in the areas mentioned above. Especially, in the lower parts of Basic Anhydrite, anhydritic-carbonate inserts, with some hydrocarbon, can be found. The Basic Anhydrite (A2) sedimentation was undisturbed, after the process was completed, the sedimentation of Older Halite forms (Na2) took place thus leveling morphologically varied Zechstein Sea Basin.

Characteristics of fields in Main Dolomite formations

Consecutive drilling works in gas and oil field and the use of latest computer technology made the thorough analysis of the area possible. The purpose of the analysis was to define the phenomena that caused partial inversion of facies layout in Zechstein Main Dolomite in reference to present seismological record; the latter being considered for years to be undisputed index for establishing barrier zone. Nowadays this criterion is not sufficient enough. The concept of paleostructural carbon barrier reconstruction we are going to present seems to find proof in the results of works completed so far but it also proves the need for broader data analysis so as to explain the problems of carbonate forms sedimentation.

Main Dolomite level in the area in question sinks gently towards NE and most hydrocarbon fields are to be found along the south edge of Gorzow Sulphate Platform. Hydrocarbons migrating towards north were stopped by tight lithological closure (edge of carbonate platform) which resulted in forming big accumulations. The Barnowko – Mostno – Buszewo (B-M-B) oil and gas field discovered in 1992 is the largest field in Main Dolomite forms in Poland so far. Moreover, within the Gorzow Carbonate Platform (GCP) such fields as Lubiszyn, Dzieduszyce and Stnowice have been found. The detailed analysis of Ca2 forms sedimentation conditions that have been conducted for several years proved the existence of Poznan Sulphate Platform (PSP). It is parallel to the Gorzow platform. On both platforms sedimentation of carbonate forms in barrier facies occurred. The Poznan platform arises considerable hopes of finding new fields. In each well drilled there remarkable accounts of hydrocarbons have been recorded. Moreover, in the area of Chrzypsko a small accumulation of oil in the transition zone between deep marine and barrier sedimentation has been found.

Sedimentation and accumulation conditions on local carbonate platforms within deep marine zone were different. Such fields were found in Sulecin, Gorzyca, Cychry, Zielin, Rozansko, Krobielewko. Sedimentation of Main Dolomite forms in barrier facies took place on thick sulphate platforms. So far no significant hydrocarbon accumulation of the Oldest Halite (Na1) occurred though its presence indicates deeper sedimentary environment. Even in such small fields as Jeniniec or Namyslin – where Ca2 forms thickness does not reach more than 5 meters *[16,5 feet]* and where deep marine facies sedimentation seems to have taken place – Werra (Pz1) forms have the character of homogenous anhydrite complex. This seems to be a significant clue useful when planning research work. Chemical composition of hydrocarbons in particular fields is a separate problem. Each field has different chemical gas composition and sulphuretted hydrogen contents. It often happens that in one field the average hydrocarbon contents is 26 %, whereas in the field situated 3 km away it reaches 52 %. The discovery of fields with medium hydrocarbon contents, below 10 % (Sulecin, Cychry, Krobielewko) should be taken into account. The gas with such small contents of hydrocarbons can be used to impound high-methane gas.

Characteristics of Main Dolomite forms paleomorphology

Carbonate barrier of Main Dolomite developed gradually. Top configuration picture of this carbonate level seen now is much different from the picture created with the use of paleostructural analysis. It shows that the main barrier ridge agreed with established sulphate Werra platforms (A1d+g). In the area in question ribbon and semi-circular paleobarrier forms are likely to be found, their feature being high dynamics of deposition environment. Organic forms in shallow waters are rich and varied. They are most exuberant in the outside part of the barrier area. From the side of lagoon organic forms die gradually and are covered with clastic material from destroyed barriers. It gathers in the inside part of sedimentation basin. That results in shallows represented by sands and gravels with considerable addition of anhydrite. In the central part of the analysed area in the lagoon zone (Międzyrzecz Depression) several small elevations with small amplitude have been interpreted. They probably represent internal barriers that developed in the lagoon zone. Drill cores material from the wells in that area indicates that the forms there are typical of isolated internal lagoon that had no inflow of fresh water. That type of carbonate forms has no reservoir properties. It is represented by beige, hard, compact, fine crystalline pelitic, partly recrystallized dolomites. Few thin stylolitic stitches and nest of black claystone can be seen there.

Local sulphate Werra platforms that constituted ''islands'' during the sedimentation of Ca2 forms can be correlated too. Main Dolomite forms on the platforms are usually represented by grainstone levels, rather than madstone or pacstone ones. Common lack of early cements in grainstones indicates that they didn't undergo vadose compaction. Therefore primary porosity could be preserved. The layers that underwent secondary cementation are characterized by low permeability thus becoming physical barriers to lateral migration of hydrocarbons.

Hydrocarbons accumulation conditions

The Main Dolomite area in question consists of the rock considered and reservoir series of hydrocarbons, and its character depends on lithofacial forming. Recently performed geochemical analyses in that area prove hydrocarbons in the Main Dolomite are syngenetic and the hydrocarbons generating potential shows both deep marine and barrier facies.

Geochemical analyses of the Main Dolomite forms state that the average TOC content is about 0,27 (0,01 ÷ 0,94 %), whereas the average BEX content is about 0,451 (0,085 ÷ 1,047 %). The kerogen content oscillates between 0,007 ÷ 0,532 %.

The organic substance in TOC > 0,3 % samples has been analysed with the use of Rock-Eval method in the Institute of Gas and Oil Mining (IGNG) in Krakow. It has been established that in the material rock type III kerogen, characterised by high oxidation degree, dominates. The organic substance in the Ca2 level in the area demonstrates high degree of reflectivity in vitrinite maturity Ro=0,7 ÷ 0,9 % which corresponds with maximal lignid hydrocarbons generating ability (so called oil window). The analysis of the organic substance character and the diagenetic development show that, the process of hydrocarbon migration and accumulation within the Main Dolomite occurred in two stages. It took place before the Cimmerian tectonic rebuilding and was crucial to the present hydrocarbon reservoir formation. Diagenetic processes (mainly anhydritization of the rocky skeleton and dissolution and secondary cementing) taking place within carbonate Ca2 forms, led to the slow filling of primary interstices that constituted perfect migration routes. The first migration

finished before Cimmerian rebuilding, when the pores were filled with anhydrite. The process may have led to the creation of the majority of lithological traps, the location of which corresponds with depositional elevation. The second migration stage was connected with the forming of present structural traps and it started after the Cimmerian rebuilding. The hydrocarbon migration in the area went in the direction of the local dipping, that is from north-east to south-west, filling in the newly created structural forms. But primary traps, which had tight lithological closures and were sealed by thick complexes of anhydrite and halite forms, were not destroyed.

Depositional elevations established thanks to paleostructural analysis at present do not manifest themselves as structural elevations but they constitute lithological traps located deeper than the ones created after the Cimmerian rebuilding. In the traps significant hydrocarbons fields may be expected.

Final conclusions

Main Dolomite research in the Western Poland area allows the following conclusions:

- In the area in question the Main Dolomite forms dip gently towards north-east;
- The drilling work in 1990 proved the existence of string of isolated elevations within the deep marine, barrier and lagoon zones Zechstein Main Dolomite. Moreover, the presence of industrial oil and gas accumulations was confirmed;
- The narrow and steep carbonate platform slope brings about landslide breccia;
- On the outer edge of the platform there probably existed a belt of shoal consisting mainly of oolitic sands acting as barriers. At the back of carbonate barriers, in more peaceful waters, sediments with higher content of carbon mud formed. Within the lagoons the zone of local shoal may by expected (shoal and oolitic layer);
- Within the carbonate platform the deposition sequence Ca2 consists of three sedimentary levels (A, B, C), formed in different sedimentation conditions each;
- The Main Dolomite forms are characterized by good reservoir properties. Porosity left by dissolved carbonate grains forming irregular cavern-like interstices rather than open slits is dominant here;
- The characteristics of organic matter and the course of diagenetic processes indicate that hydrocarbons migration and accumulation took place in at least two stages – before and after the Cimmerian rebuilding;
- Elevations in the Main Dolomite level, established on the basis of seismic data interpretation, do not correspond with the highest thickness zones and the area most advantageous reservoir properties in the B-M-B field;
- Lithofacial and petrophysical characteristics of Ca2 forms indicate that there may exist new, separate hydrocarbon fields in the area.

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