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Sedimentary basin analysis of the Polish Lowlands — an introduction

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The project "Sedimentary basin analysis of the Polish Lowlands" has been designed as a vehicle for introducing research strategy of the basin analysis to Polish regional geological studies and hydrocarbon potential assessment on a basin scale. The project has been accomplished during October 1994 to September 1996 by a team of collaborators from the Polish Geological Institute (M. Narkiewicz, leader), Academy of Mining an Metallurgy (M. Kotarba, principal investigator), Geological Bureau GEONAFTA (L. Antonowicz, principal investigator), Oil and Gas Institute (J. Kruczek, principal investigator). Five epicontinental basins have been studied: Devonian, Carboniferous, Rotliegend, Zechstein and Mesozoic. Broad spectrum of methods has been adopted, including: sedimentological and sequence-stratigraphic techniques, sophisticated analyses of source and reservoir rocks, organic maturity measurements (R_o, CAI, T_{max}), quantitative subsidence analysis, and numerical modelling of hydrocarbon generation processes.

INTRODUCTION

Until late eighties, the sedimentary basin analysis, conceived both as petroleum exploration tool and as regional geological research strategy, was hardly perceived among Polish geologists. There had been a remarkable progress in several aspects of basin analysis treated as separate fields of research — e.g. in stratigraphy, sedimentology, subsurface mapping or structural studies. One can also mention several successful attempts to synthesize facies, palaeogeographic and structural aspects of Polish basins including, in particular, the Permian and Mesozoic ones. However, the leading concept of the basin analysis, i.e. an integration of different aspects and methods, including quantitative modelling approach, was not popularized neither in academic circles nor in the Polish Geological Survey and among exploration geologists. Ultimately, the reasons for this situation can be traced back to a political history of Europe and its direct consequences — political, economic and scientific barriers separating Western countries from the Eastern Block and leading to difficult access to scientific information, problems with modern technology acquisition etc.

It was not until the political breaktrough in Central and Eastern Europe in the years 1989–1990 when it became possible to analyse and discuss in an open way the degree of delay of Polish geology relative to leading scientific centres and petroleum companies in Western countries. One of consequences of such discussions was a proposal of introducing the integrated methodology of basin analysis to geological regional studies in Poland (M. Narkiewicz, 1991). Soon, the Polish Geological Institute, acting as a research unit of the Polish Geological Survey, started methodological and logistic preparations to undertake this task. At the same time, elements of a basin analysis started to be introduced into exploration activities of the Polish Oil and Gas Company (POGC) (e.g. K. Betlej, J. Zagórski, 1992) and into detailed analytical and modelling studies of petroleum source rocks carried in the Academy of Mining and Metallurgy (AMM) in Cracow under the leadership of A. Górecki and M. Kotarba (see the series of short papers *fide* W. Górecki, ed., 1996). In the above institutions the initiation of research according to the spirit of sedimentary basin analysis, was intimately connected with acquisition and implementation of modern research and exploration techniques including seismic processing, computer methods and laboratory equipment.

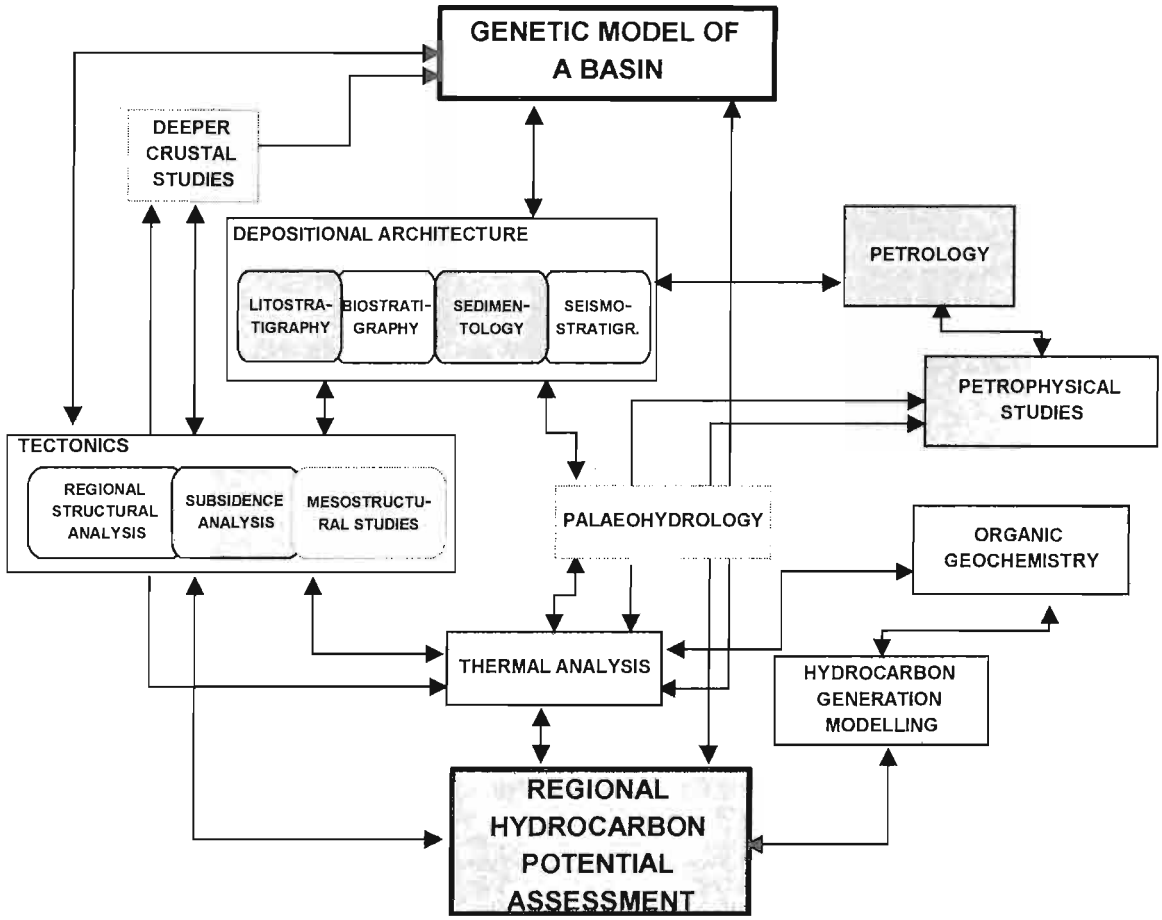

Fig. 1. Flow chart summarizing various aspects and main objectives of sedimentary basin analysis
Shaded boxes represent aspects extensively studied during the described project; blank boxes with heavy outlines — partly studied aspects; dotted outlines — not studied

Schemat obrazujący różne aspekty i główne cele analizy basenów sedymentacyjnych
Okienka zacieniowane dotyczą aspektów szeroko uwzględnionych w omawianym projekcie; okienka bez zacieniowania — zagadnienia częściowo uwzględnione; kontur kropkowany — nie uwzględnione

In 1993 the concept of a wide application of basin analysis in geological investigations gained a support from the Polish Geological Administration in the framework of the Ministry of Environmental Protection Natural Resources and Forestry (MEPNRF). The idea was put forward that a major research project on basin analysis will be proposed to and, eventually, granted by the Committee for Scientific Research (CSR). As a consequence of the Ministry's initiative the Committee announced in early 1994 an open competition for conducting the project PBZ 02-03 entitled "Sedimentary basin analysis of the Polish Lowlands". The Polish Geological Institute, represented by the present author, prepared and submitted the formal proposal jointly with three other institutions: the POGC (represented by the Geological Bureau GEONAFTA), the AMM and the Oil and Gas Institute (OGI) in Cracow.

As a result of the competition procedure our proposal has been approved and the team of collaborators from the above institutions was granted financial support to conduct the two-year project starting in October 1994. According to the proposal, PGI was chosen the leading institution with the present author as the leader of the project. Remaining three institutions acted as co-operating units with following principal investigators: Maciej Kotarba (AMM, Cracow), Lech Antonowicz (GEONAFTA, Warsaw) and Józef Kruczek (OGI, Cracow). The project was completed according to the schedule. The final report was highly rated by the reviewers both in the MEPNRF and in the CSR. The initial reports on the results were presented during the scientific conference held in PGI from 10 to 11 of April, 1997, and the first summary of the results was published recently in Polish (M. Narkiewicz, 1997). A volume containing most important results of the project is scheduled for publication in 1998 (in Polish). The present special issue of *Geological Quarterly* is the first of planned publication series summarizing the results of the project in English.

PURPOSE AND SCOPE OF THE PROJECT

Basing on initial discussions in the PGI the project was designed as a vehicle for introduction and application in Poland of a modern basin analysis methodology as adopted to specific domestic needs and conditions. Thus, it was envisaged as a "pilot" study opening a new approach to both basic regional geological studies and petroleum assessment on a basin scale. At the same time, however, it was planned, that the project will generate new data and new geological models or interpretations leading to better understanding of the important Polish oil- and gas-bearing basins. This in turn will aid Geological Administration in their task of preparing and making decisions related to geological concessions for petroleum exploration and production. It will also help the state-owned petroleum company, the POGC, to better assess the petroleum potential of Polish basins, and to focus its planned exploration activities.

As can be seen from above considerations the main goals of the project were somewhat intermediate between basic scientific aims of regional geology and purely applied exploration objectives of petroleum industry. The scope of the project included three main tasks: (1) compilation of computerized data-base for deep wells from the Polish Lowlands, (2) basin analysis of the Devonian, Carboniferous, Permian and Mesozoic basins, and (3) assessment of target areas for a future petroleum exploration. The three aspects of the basin analysis have been pointed out as particularly important for the project: depositional architecture, burial history and subsidence development. It was clear that the main emphasis was put here on petroleum-oriented regional study rather than on genetic (structural) reconstructions and modelling (*cf.* Fig. 1). Consequently, detailed planning of the project focused on methods leading more or less directly to assessment of a hydrocarbon potential of studied basins.

Figure 1 shows an idealized scheme of different interrelated methods and aspects constituting a complete basin analysis. Marked are those fields of research that were included into the present project (described in more detail below). It can be seen that not included were such aspects related to a genetic basin modelling, as deep crustal geophysical investigations and, partly, regional structural analysis. On the other hand, mesostructural analysis was also neglected as it is related to hydrocarbon exploration on a prospect scale rather than to a regional assessment. Palaeohydrological aspects of basin modelling are very important for estimating petroleum potential, particularly computer methods allowing 2-D reconstructions of basin-scale fluid-flow patterns in time. However, this aspect has not been pursued because of time and financial limitations. Obviously, the fields of research not covered by our analytical studies were taken into account basing on available results of previous investigations. This is particularly true for geophysical, stratigraphic and structural studies. Flow diagram in Figure 2 summarizes the overall structure of investigations emphasizing relationships between different areas of research carried out by teams from four co-operating institutions.

The regional and stratigraphic scope of the project has been defined rather widely. The regional term "Polish Lowlands" embraces whole northern and central part of the country. In addition, Devonian to Cretaceous deposits represent most of sedimentary fill accessible to direct investigations in this area. This sedimentary fill can be attributed to at least five independent superimposed basins each with its unique structural and palaeogeographic framework and history of development: Devonian, Carboniferous, Rotliegend, Zechstein and Mesozoic (Figs. 3–7). Thus, it appeared neccessary to define certain regional and stratigraphic priorities rather than dissipating efforts on too-many objectives. In the light of previous studies the most prospective from exploration point of view are the first four basins, and laboratory analyses of potential source and reservoir rocks concentrated on those basins. The Mesozoic polyhistory basin is important in that it preserves a record of a complex sedimentary fill and subsidence history relevant to understanding the burial processes in older source and reservoir rocks, including HC

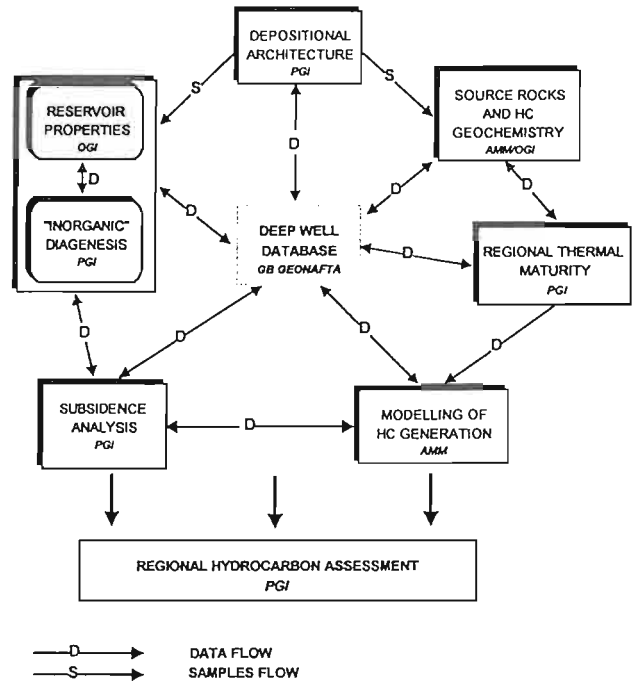

Fig. 2. Flow chart showing relationships between various methodological blocks in the described project

Indicated are institutions responsible for particular blocks: PGI — Polish Geological Institute, AMM — Academy of Mining and Metallurgy, GB GEONAFTA — Geological Bureau GEONAFTA, OGI — Oil and Gas Institute

Schemat zależności między różnymi blokami metodologicznymi opisywanego projektu

Wskazano instytucje odpowiedzialne za poszczególne badania: PGI — Państwowy Instytut Geologiczny, AMM — Akademia Górniczo-Hutnicza, GB GEONAFTA — Biuro Geologiczne GEONAFTA, OGI — Instytut Górnictwa Naftowego i Gazownictwa

generation and migration.Therefore, the main emphasis was put on the Mesozoic depositional architecture and tectonic development. The first of those aspects is the main subject of the present Special Issue.

Separate description of both the Permian basins is justified by the differences in their geological structure, and, in particular, by a different style of the basin-fill development. Continental red-bed type deposits of the Rotliegend lack any source rocks while good-quality reservoir rocks are ubiquitous. The Zechstein basin represents a well-known example of closed (self-sufficient) petroleum system with well developed source, reservoir and seal rocks. In the Zechstein basin the studies focused on the Main Dolomite level (Ca2) which appears most prospective so far. The detailed analytical studies of the Devonian and Carboniferous basins were limited to two broad areas: Pomerania and Radom–Lublin (Figs. 3–4). The latter does not belong, strictly speaking, to the Polish Lowlands, it was, however, included into the present project as it appears interesting for petroleum industry.

The final report of the project was constructed basing on stratigraphical key, i.e. it contained, apart from introductory volume, five volumes devoted to particular basins and covering different aspects, from general setting and configuration, through depositional architecture, tectonic subsidence history, burial history (organic and inorganic diagenesis, HC generation modelling) to conclusions on petroleum potential. Contrary to this, when planning the publication of the results in the *Geological Quarterly,* we adopted the topical key reflected also in the present Special Issue.

MATERIALS AND METHODS

General methodology of a sedimentary basin analysis has been extensively presented in several textbooks (e.g. P. A. Allen, J. R. Allen, 1990; A. D. Miall, 1990; G. Einsele, 1992). Here, I will focus on specific approaches and methods applied for the purposes of described project.

In general, geologic materials used during the course of the project were mostly obtained from selected deep wells drilled during last 40 years by the PGI and the POGC. Limited amount of seismic data used for the project is commented below. The number of studied wells for particular basins was as follows: Devonian — 49 (without CAI studies), Carboniferous — 30 (without CAI studies), Rotliegend — 22, Zechstein — 41, Mesozoic — 59 (see Figs. 3–7). The cores have been partly redescribed for sedimentological purposes whereas in other cases existing geological and geophysical data has been used. Having in mind that the total number of deep wells drilled so far in the Polish Lowlands exceeds 5000, it was very important, with limited time and research capabilities, to carefully select sections for detailed studies. Sampling program was planned after detailed analysis and discussion of previous work, which resulted in defining stratigraphic levels of existing and potential source and reservoir rocks in particular basins and study areas. In turn, sampled well sections have been specified basing on two main criteria: (1) representativeness for studied horizons, and (2) availability and state of preservation of core material. In the case of depositional architecture and tectonic subsidence studies, the sections have been selected so as to cover full spectrum of (known so far or expected) main palaegeographic/facies and palaeostructural domains.

The detailed methods of study described below are connected with an analysis of particular aspects of sedimentary basins. It must be stressed, however, that the value of the methods to a large degree consists in their integration. Thus, during the course of the present project much emphasis was put on comparisons and feedbacks between various methods and approaches. The most important examples of such integration include: analysis of source and reservoir rocks within the framework provided by the study of depositional architecture, intimately connected sedimentological, petrological and petrophysical analyses of reservoir rocks or interconnected quantitative subsidence analysis and hydrocarbon generation modelling.

Brief methodological account given below is merely a general overview of methods and techniques applied during the project studies. Details of particular analytical methods and more detailed description of study materials will be specified in papers dealing with particular aspects of the project.

ANALYSIS OF DEPOSITIONAL ARCHITECTURE

Sedimentological and stratigraphic studies were aimed at reconstructing major elements of the sedimentary fill within the framework of particular basins. At the same time they provided a common reference frame linking other analytical blocks and thus providing cohesive model of various aspects of a basin development. The studies have been conducted in the PGI and co-ordinated by M. Narkiewicz (Devonian), late A. M. Żelichowski and M. Lipiec (Carboniferous), H. Kiersnowski and J. Pokorski (Rotliegend), R. Wagner (Zechstein) and S. Marek and R. Dadlez (Mesozoic).

In the present project a depositional system has been assumed the basic element of sedimentary fill. At the same time main constituents of the petroleum system, i.e. source, reservoir and sealing rocks, in many cases can be adequately

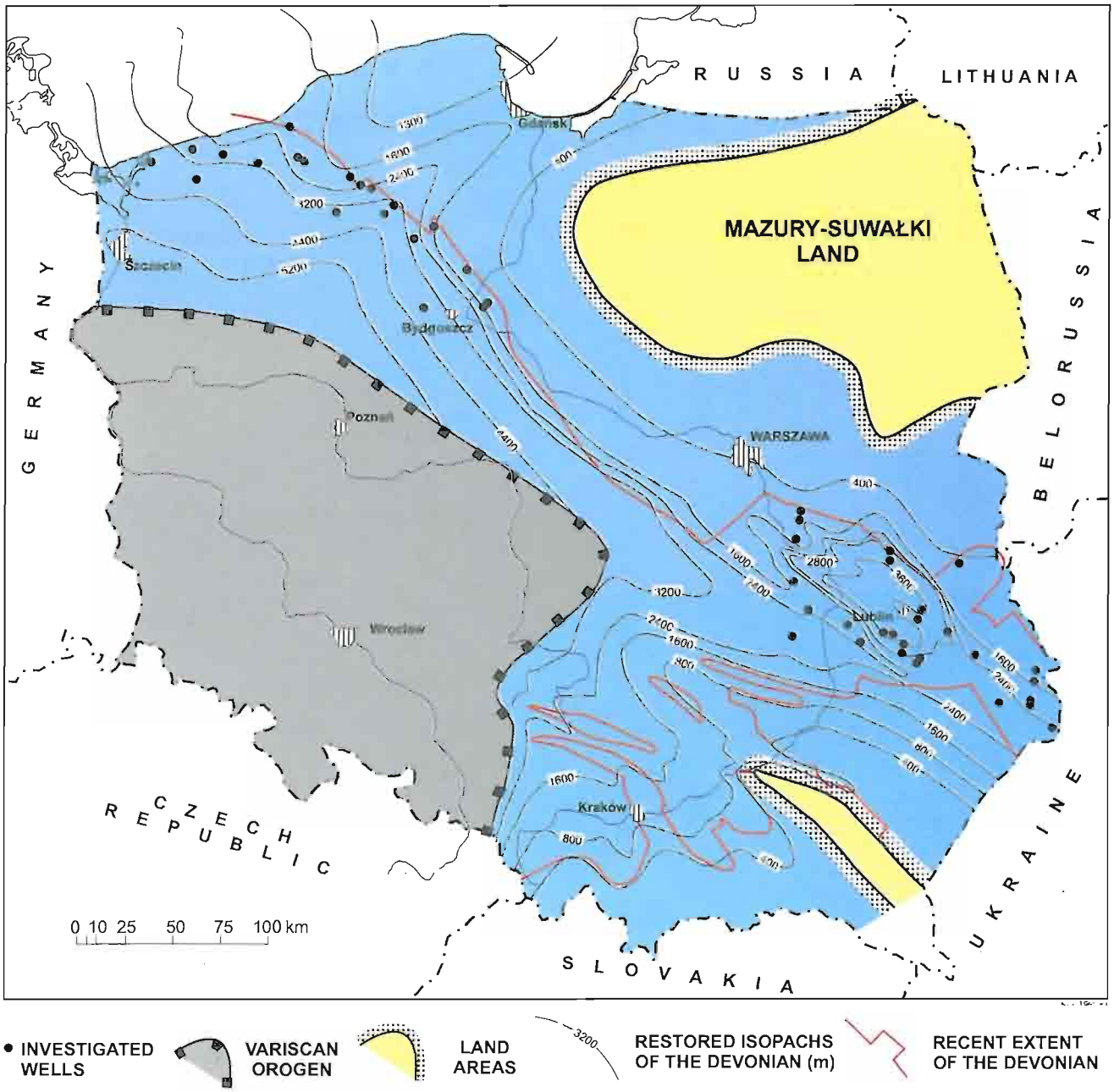

Fig. 3. Location of studied deep wells against the general background of the Devonian epicontinental basin in Poland (marked in blue) (after L. Miłaczewski and M. Narkiewicz)

Lokalizacja badanych otworów wiertniczych na tle dewońskiego basenu epikontynentalnego w Polsce (zaznaczone na niebiesko) (według L. Miłaczewskiego i M. Narkiewicza)

described and interpreted in terms of depositional systems. Depositional system is "...three-dimensional assemblage of lithofacies, genetically linked by active or inferred processes and environments..." (H. W. Posamentier *et al.*, 1988). W. E. Galloway (1989) defines depositional system as three-dimensional assemblage of genetically linked lithofacies recording main palaeogeomorphological features of a basin. In turn, according to the definition by P. A. Allen and J. R. Allen (1990), "...depositional systems are sets of depositional environments linked by the process of sediment dispersal...". All these, partly complementary definitions have been applied when defining depositional systems in the present project.

Combining depositional systems into higher-rank units, i.e. systems tracts, depositional sequences or transgressive-regressive cycles, has been treated less rigorously, without preference for any of current stratigraphic concepts. In most cases, the notion of depositional (transgressive-regressive, T-R) cycles has been applied rather than depositional sequen-

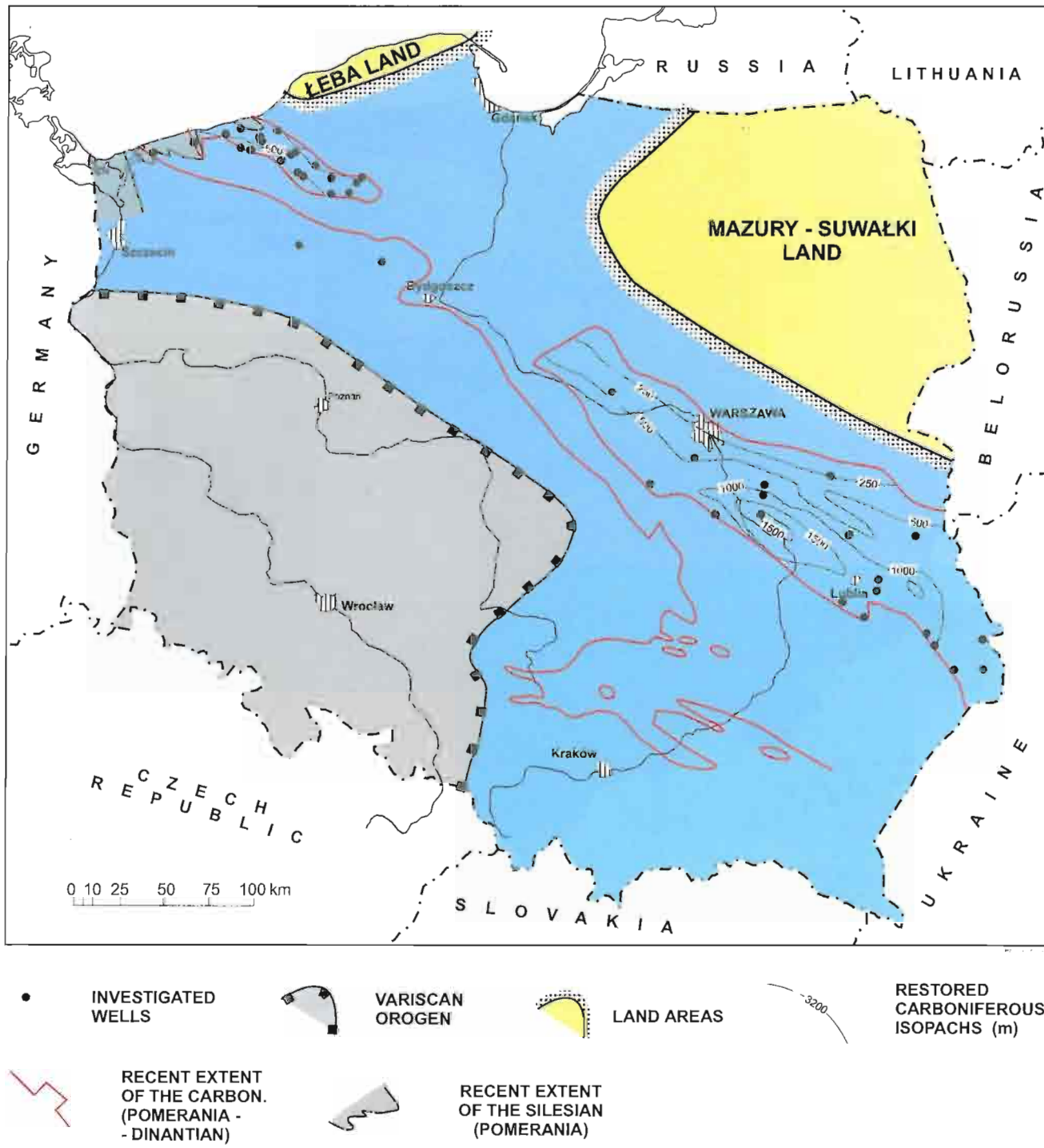

Fig. 4. Location of studied deep wells against the general background of the Carboniferous epicontinental basin in Poland (marked in blue) (after A. M. Żelichowski and M. Lipiec)

Lokalizacja badanych otworów wiertniczych na tle karbońskiego basenu epikontynentalnego w Polsce (zaznaczone na niebiesko) (według A. M. Żelichowskiego i M. Lipca)

ces in the strict sense of P. R. Vail *et al.* (1977). In general, the cycles comparable to 3rd order sequences (i.e. with a duration 1–10 Ma) have been distinguished. In some instances it was possible to define lower-rank units. It appears, basing i.a. on the results of the present project, that T-R cycles adequately reflect a stratigraphic record of epicontinental basins, as represented mostly by well data. This is in contrast to seismostratigraphic studies of continental margins. It must be also

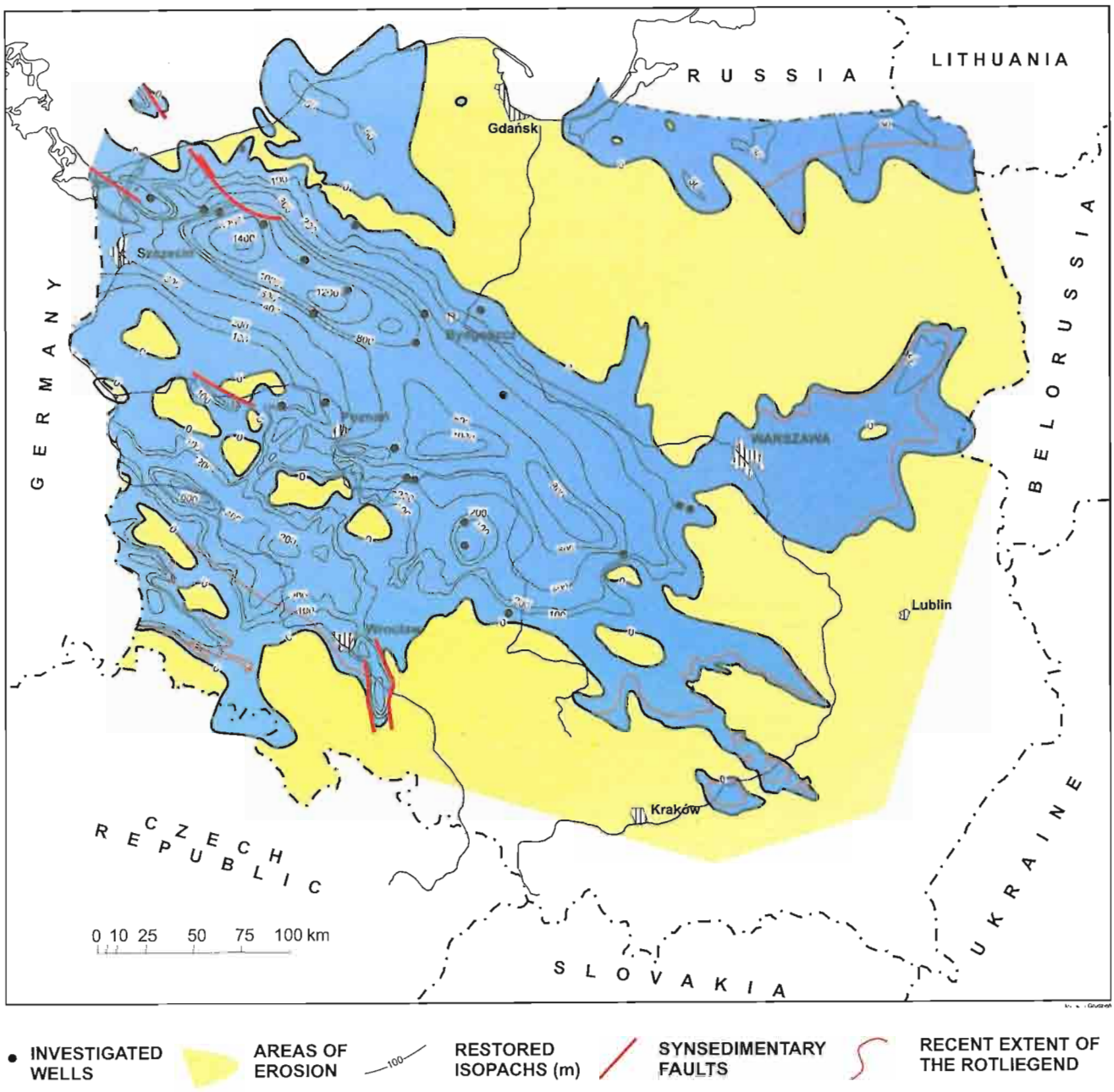

Fig. 5. Location of studied deep wells against the general background of the Upper Rotliegend basin in Poland (marked in blue) (after J. Pokorski)

Lokalizacja badanych otworów wiertniczych na tle basenu czerwonego spągowca w Polsce (zaznaczone na niebiesko) (według J. Pokorskiego)

stressed that during the present investigations the main emphasis was on descriptive rather than genetic aspects of a depositional cyclicity. In particular, no *a priori* assumptions have been adopted for mechanism of cyclicity in studied sections. However, in several examples it was possible to constrain possible origin of cycles, e.g. by relating described cycles to well-known continental or even global sedimentary events.

Depositional systems and cycles have been defined in key well sections basing on sedimentological observations and on an analysis of wireline logs. Thereafter, the cycles have been correlated between the sections using characteristic geophysical levels in most cases. The latter have been distinguished mostly in standardized gamma and neutron-gamma logs. The standardization procedure has been carried out by J. Szewczyk (PGI).

Along with new sedimentological descriptions, also numerous published and unpublished reports on particular well sections has been used. Newly defined depositional systems and cycles have been referred, wherever possible, to

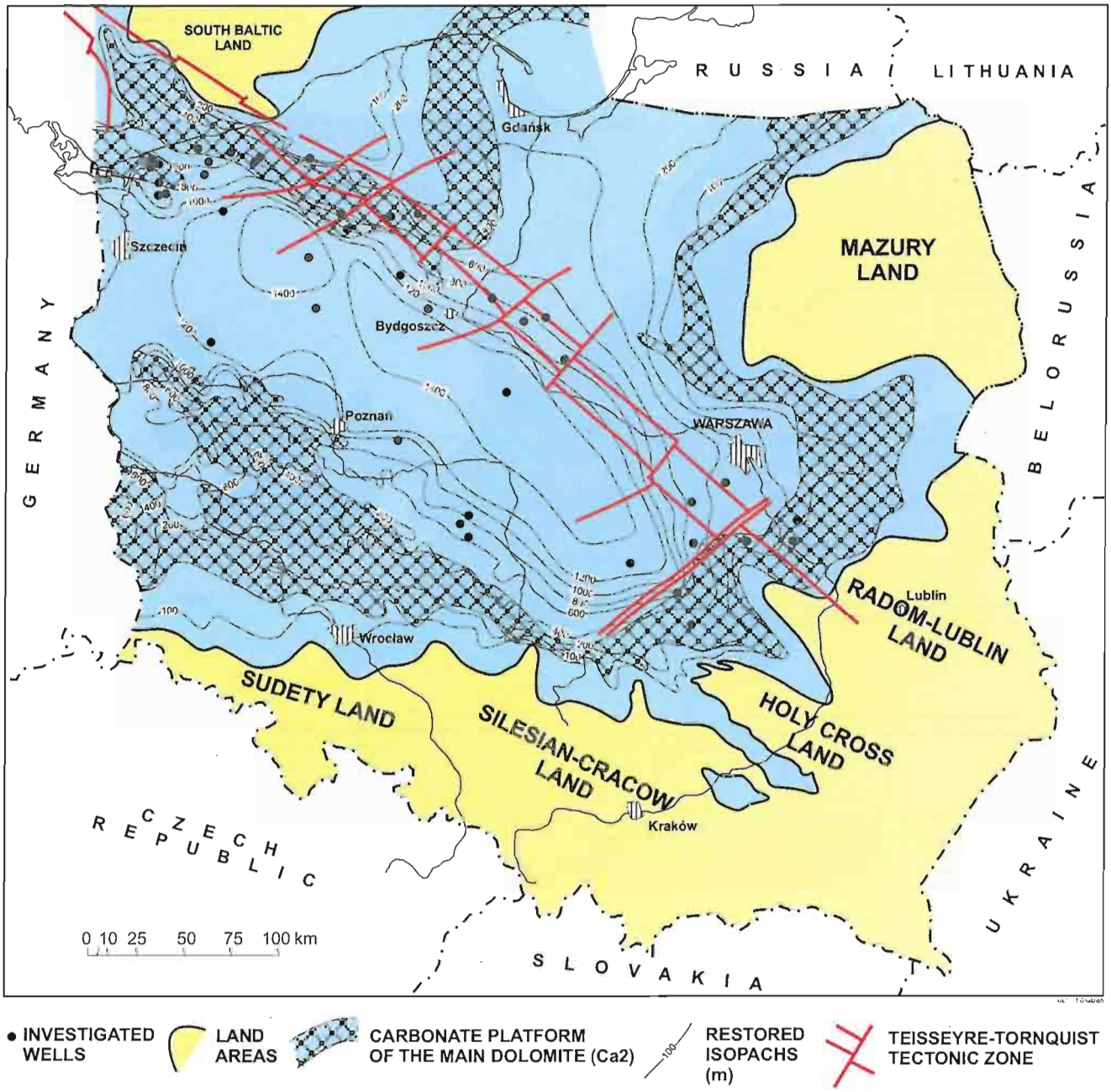

Fig. 6. Location of studied deep wells against the general background of the Zechstein basin in Poland (marked in blue) (after R. Wagner)

Lokalizacja badanych otworów wiertniczych na tle cechsztyńskiego basenu epikontynentalnego w Polsce (zaznaczone na niebiesko) (według R. Wagnera)

existing stratigraphic, in particular litostratigraphic subdivisions. Bio- and chronostratigraphic correlations have been based mostly on previous results. Limited biostratigraphic analysis based on conodonts has been undertaken only in the case of the Devonian and Carboniferous basins. Those studies have been planned taking into account their capability of supplying in relatively short time valuable results applicable to both biostratigraphic dating and thermal maturity assessment (CAI — see below).

At the early stage of the project an attempt was undertaken to integrate seismostratigraphic techniques with studies based on well data from the Devonian, Carboniferous and Mesozoic basins. In all studied examples except for the Middle to Upper Devonian in the Lublin area, the attempt failed due to an unsatisfactory quality of seismic data. The latter was caused by weak resolution of the seismic sections relative to often small thicknesses of architectural elements, by screening effect of the overlying sediments, e.g. Carboniferous clastics or Zechstein evaporites, or by generally low quality of the record

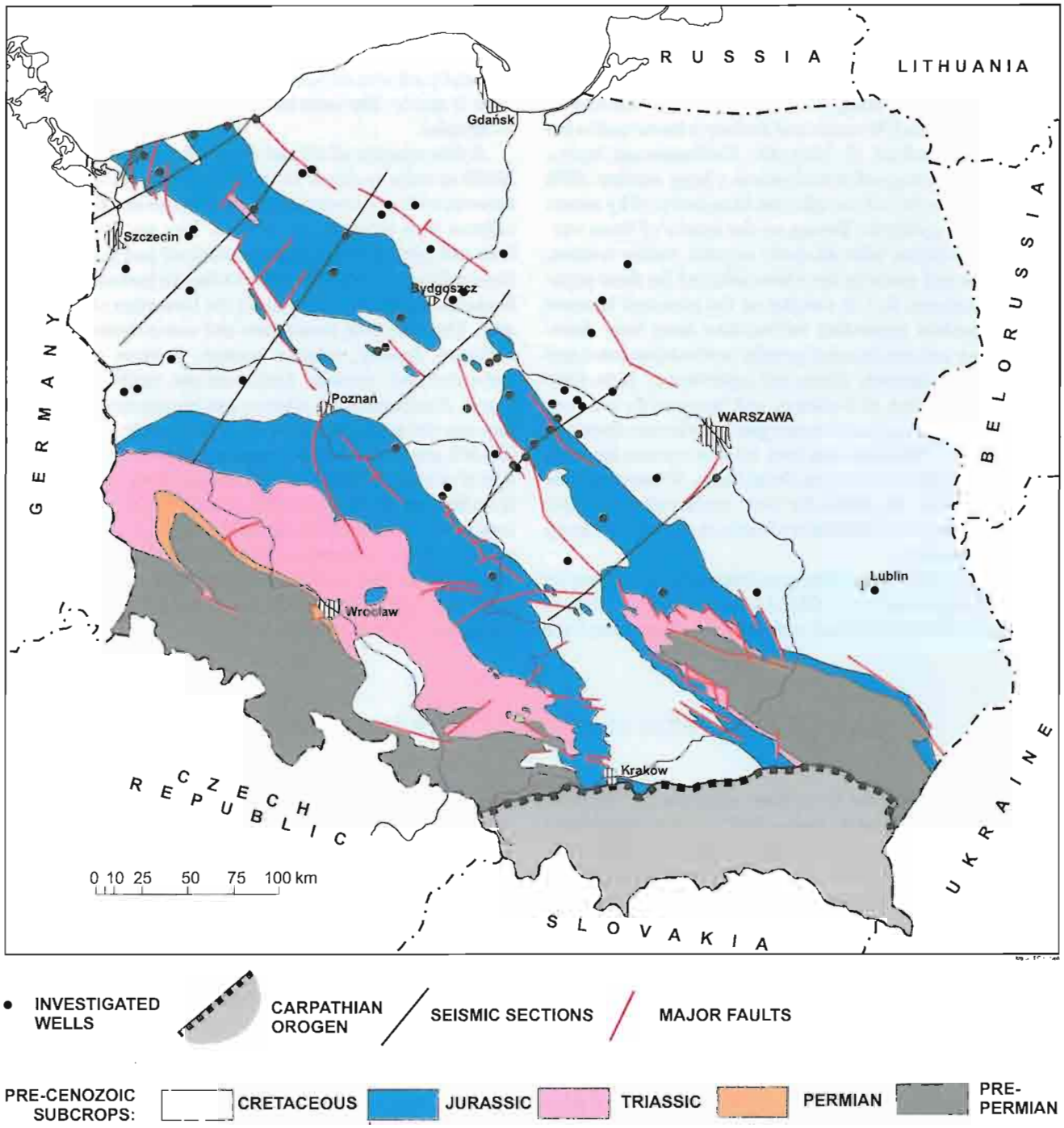

Fig. 7. Location of deep wells and seismic cross-sections with studied Mesozoic interval against the simplified geological map of Poland without Cenozoic (after S. Marek and K. Leszczyński)

Lokalizacja otworów wiertniczych i przekrojów sejsmicznych, w których badano utwory mezozoiku, na tle uproszczonej mapy geologicznej odkrytej (według S. Marka i K. Leszczyńskiego)

as in the case of the near-surface Mesozoic complexes. In order to illustrate general features of the present geometry of Permian to Mesozoic basins, six regional cross-sections have been compiled and interpreted basing on partly reprocessed seismic sections (see Fig. 7 for a location). The reprocessing has been conducted in the Geofizyka Toruń and Kraków Divisions of POGC under the guidance of L. Antonowicz. The lines, trending SW–NE, have been situated between Baltic Sea and the Holy Cross Mts. and thus perpendicularly to the axis of the inverted Permian–Mesozoic Mid-Polish Trough.

ORGANIC GEOCHEMISTRY OF SOURCE ROCKS AND HYDROCARBONS

Geochemical studies of source rocks have been carried out in the Academy of Mining and Metallurgy under the leadership of M. Kotarba (Devonian and Zechstein basin) and in the Oil and Gas Institute (I. Matyasik; Carboniferous basin). During the first stage of investigations a large number (680) of potential source rock samples has been analysed by means of Rock Eval pyrolysis. Basing on the results of these analyses, 384 samples with adequate organic matter content, genetic type and maturity have been selected for more sophisticated analyses. In 154 samples of the extracted bitumen content (Soxhlet apparatus) subfractions have been determined using column chromatography method (saturated and aromatic hydrocarbons, resins and asphaltenes). In 66 samples the distribution of n-alkanes and isoprenoids has been analysed by capillary gas chromatography, whereas elemental composition of bitumens and their sulphur content has been determined in several samples. In addition, 30 samples have been analysed in the AMM for their stable carbon isotopic composition in particular bitumen fractions and kerogen using mass spectrometry.

Additional analyses of kerogen composition in 25 samples have been carried out in the OGI. Concentration of carbon in kerogen has been determined, and kerogen concentrates have been analysed with respect to their elemental composition (C, H, O, N and S). The same laboratory analysed humic acids in 58 samples.

A few samples of oil and gas have been analysed in the AMM in order to throw some light on genetic relationships between analysed source rocks and gaseous and liquid hydrocarbons from selected occurrences. Ten samples of oil has been analysed of which four represent oil and gas accumulations within the Zechstein Main Dolomite horizon in western Pomerania whereas six are from the Devonian of the Lublin area. The following parameters and components have been analysed: density, sulphur content, fraction composition (saturated and aromatic hydrocarbons, resins and asphaltenes), distribution of n-alkanes and isoprenoids using capillary gas chromatography method, biomarker analysis using GC-MS apparatus as well as stable carbon isotope composition of oils and their particular fractions. Four gas samples are from the same Pomeranian Main Dolomite reservoirs as in the case of oil samples. The molecular composition and stable carbon isotope composition of methane, ethane and propane and stable hydrogen isotope composition of methane have been analysed by means of gas chromatographs and mass spectrometers, respectively.

PETROPHYSICAL STUDIES OF RESERVOIR ROCKS

Reservoir properties have been analysed by the team under the leadership of P. Such (OGI) in 50 selected wells representative of depositional systems potentially or actually important as reservoirs in the Devonian, Carboniferous, Rotliegend and Zechstein basins. Total of 580 samples have been analysed using helium pycnometer and porosimetric equipment AutoPore 9220 based on mercury injection method. The measured parameters are the following: skeletal density obtained both from helium pycnometer and from porosimeter, total porosity, bulk density, effective porosity, average pore diameter, porosity (pores with diameters exceeding 1 μm), specific surface, percentage of pores with diameter exceeding 1 μm, treshold diameter, histeresis and permeability.

The results include the cumulative plot of capillary pressure which forms a "fingerprint" of each sample. One of the measured parameters, the treshold capillary pore diameter, is regarded as an estimate of a maximum capillary diameter capable of conducting petroleum fluids. Statistical processing of the data has been accomplished using QUATTRO program.

PETROLOGICAL INVESTIGATIONS OF RESERVOIR ROCKS

Petrological studies have been focused on the same reservoir horizons as petrophysical measurements. The purpose of the studies was twofold. First, they were aimed at explaining the measured reservoir properties in terms of sedimentary and diagenetic characteristics. To obtain compatibility of both data sets, the petrological samples have been localized in the same core intervals (within the range of a few centimetres) as petrophysical ones. The second objective was to reconstruct a sequence of diagenetic events and, eventually, relate them to geological history of studied horizons. However, in most cases, it appeared impossible at this stage of investigations, to precisely reconstruct timing of diagenetic events as related, in particular, to modelled phases of hydrocarbon generation and expulsion. This question must remain open until more detailed petrological data, including stable-isotope and fluid inclusion studies, will be integrated with other reservoir investigations, e.g. embracing tectonic analysis of cores.

Petrological study was accomplished by the team from the PGI under the leadership of A. Maliszewska. The study was based on classical microscopic observations of stained thin sections in transmittent light. They have been supplemented by observations of selected samples using SEM technique,

cathodoluminescence, and EDS microprobe. The above techniques have been applied mostly to characterize qualitatively and quantitatively cement generations important for reservoir parameters of the studied rocks.

SUBSIDENCE ANALYSIS

At the beginning of the described investigations there had been only a single study on quantitative subsidence analysis of the Permian–Mesozoic in the Mid-Polish Trough using backstripping method (R. Dadlez *et al.*, 1995). During the present studies such an approach has been extended to include the Devonian to Carboniferous subsidence evolution of the Polish Lowlands. The purpose of the analysis was twofold: (1) to compile and verify geohistory type of data neccessary for hydrocarbon modelling procedures, (2) to throw some light on possible scenarios and mechanisms of the basin development. Limited complementary study of 10 sections has been undertaken to supplement earlier Permian–Mesozoic results. The Devonian–Carboniferous subsidence has been studied in 14 sections: 10 located in the Radom–Lublin area and 4 in the Pomerania area. In most cases the data have been compiled from two or even three well sections located as closely as possible. Missing (eroded) thicknesses have been estimated basing on previously prepared palaeotectonic maps. The backstripping calculations have been carried out by P. Poprawa using Platte River 1-D BasinMod software assuming D. A. Falvey and M. F. Middleton (1981) model of compaction processes. The time scale was that of W. B. Harland *et al.* (1990) with some modifications in the case of the Permian to Mesozoic (*cf.* R. Dadlez *et al.*, 1995), and including revision of the Tournaisian radiometric dates, published by B. Fordham (1992).

THERMAL MATURITY STUDIES

The study of regional patterns of thermal maturity of source rocks has been accomplished basing on results of measurements of the conodont color alteration index (CAI) for the Devonian and Carboniferous basins, on vitrinite reflectance data (R_o) for the Devonian, Carboniferous and Zechstein basins, and on the T_{max} data obtained from Rock Eval investigations carried out in the AMM and OGI (Radom–Lublin area of the Carboniferous basin and the Zechstein basin). The results have been presented on a series of digitized maps (scale 1:1 000 000) prepared using SURFER software.

CAI study was based on original data acquired for the purpose of the present project by H. Matyja, K. Narkiewicz and S. Skompski. It is the first CAI study in Poland with such a wide regional and stratigraphic scope and amount of material (424 determinations in 108 deep wells). Maps of $\%R_o$ distribution have been based on the results of previous investigations carried out in the Polish Geological Institute during the last several years under the leadership of I. Grotek.

The maps of various maturity indices and parameters for the same stratigraphic intervals have been compared with each other in order to determine common patterns and differences, if any. Thereafter, the regional levels of thermal maturity have been discussed and explained in terms of subsidence and thermal history of each basin. Lastly, the maps have been used to determine a regional distribution of hydrocarbon generation windows.

MODELLING OF HYDROCARBON GENERATION AND EXPULSION

1-D numerical modelling of hydrocarbon generation and expulsion has been undertaken by the group led by M. Kotarba (UMM) in order to constrain possible scenarios of petroleum system development by estimating time of probable primary migration processes. In addition, it was possible to estimate amount of hydrocarbons generated in time for unit weigth of a source rock. Altogether seventeen well sections has been selected for modelling, basing on the results of geochemical source rock studies (mostly Rock Eval pyrolysis), and also taking into account, as far as possible, the whole range of subsidence/thermal history scenarios in the studied basins. Given a limited number of modelled sections, the emphasis was put on their representativeness for at least major domains of particular superimposed basins, characterized by specific sedimentary, structural and thermal development.

Two methods have been applied: Lopatin's TTI method of graphic modelling of oil and gas windows development (e.g. D. W. Waples, 1980), and numerical modelling using the French GENEX software. The latter, in addition to estimating a timing of consecutive hydrocarbon generation phases, also calculates hydrocarbon potential of source rocks through time.

REGIONAL HYDROCARBON POTENTIAL ASSESSMENT

Basing on all available geological material, mostly on original data and interpretations generated during the course of the project, it has been attempted to broadly outline — basin by basin — conclusions pertinent to further petroleum exploration strategies in the Polish Lowlands. The limited time and materials available precluded detailed quantitative evaluation of hydrocarbon potential. This task remains open for future regionally-oriented basin analysis studies. It must be kept in mind, however, that more rigorous basin evaluation will require statistical quantitative methods to be applied, with vast numerical data-bases available and suitable software to process the data (e.g. P. A. Allen, J. R. Allen, 1990; G. E. Reinson *et al.*, 1993; R. Kudrewicz, 1995).

The present considerations regarding prospects of hydrocarbon exploration referred to a concept of a petroleum system (recently discussed e.g. by L. B. Magoon and W. G. Dow, 1994). Thus, particular elements of the system in each of the basin have been analysed and confronted in order to define at least broad areas and/or stratigraphic units being potential targets of a future exploration. Such an approach had its limitations in the present project as some of the elements of the system were more thoroughly studied than the others.

Particular emphasis was put on regional development of source rocks and their thermal history. Timing of hydrocarbon generation and migration has been modelled using 1-D numerical techniques without taking into account spatial development of hydrocarbon migration and its entrapment (possible only in 2-D modelling). Regional topseal rocks have been analysed basing exclusively on available previous results. Lastly, geometry of traps and timing of their formation have not been analysed as this would require extensive structural studies based i.a. on seismic materials. With all these limitations in mind, and given rather low density of selected data throughout studied basin, it was still possible to point out several guidelines for petroleum explorations that either were new or confirmed/substantiated earlier hopes or misgivings.

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ANALIZA BASENÓW SEDYMENTACYJNYCH NIŻU POLSKIEGO — WSTĘP

Streszczenie

Zamawiany projekt badawczy „Analiza basenów sedymentacyjnych Niżu Polskiego" (PBZ 02-03) realizowany był od października 1994 r. do września 1996 r. na wniosek Ministerstwa Ochrony Środowiska Zasobów Naturalnych i Leśnictwa z funduszów Komitetu Badań Naukowych. Badania wykonywał zespół pracowników Państwowego Instytutu Geologicznego (kierownik projektu — M. Narkiewicz) przy współpracy Akademii Górniczo-Hutniczej (główny wykonawca — M. Kotarba), Polskiego Górnictwa Naftowego i Gazownictwa (L. Antonowicz) i Instytutu Górnictwa Naftowego i Gazownictwa (J. Kruczek). Intencją wnioskodawców projektu było wprowadzenie na szerszą skalę do krajowych geologicznych badań regionalnych i naftowych zespołu metod badawczych i poszukiwawczych określanych mianem analizy basenów sedymentacyjnych (fig. 1 i 2). Bezpośrednim celem projektu było stworzenie nowoczesnych podstaw naukowych prognozowania perspektyw występowania węglowodorów w basenach Niżu Polskiego. Badania objęły epikontynentalne baseny Niżu: dewoński (fig. 3), karboński (fig. 4), czerwonego spągowca (fig. 5), cechsztyński (fig. 6) i mezozoiczny (fig. 7). Zadania cząstkowe obejmowały: (1) stworzenie komputerowej bazy danych kluczowych głębokich otworów wiertniczych, (2) analizę wymienionych basenów z uwzględnieniem stratygrafii sekwencyjnej, historii subsydencji i historii pogrzebania oraz (3) ocenę perspektyw występowania węglowodorów w poszczególnych basenach.

Do badań wykorzystano dostępne materiały wiertnicze i geofizyczne oraz wyniki dotychczasowych prac. Szczegółowe badania analityczne objęły wytypowane poziomy skał potencjalnie macierzystych i zbiornikowych oraz wybrane obszary w obrębie basenów (fig. 3–7). Figura 2 obrazuje relacje między poszczególnymi blokami badawczymi i ogólnie informuje o wykonawcach badań. Wachlarz metod zastosowanych w trakcie badań jest bardzo szeroki: od skomplikowanych analiz chemicznych za pomocą chromatografu gazowego i spektrometru masowego (izotopy, biomarkery), przez badania właściwości zbiornikowych nowoczesnym piknometrem helowym i porozymetrem, obserwacje petrologiczne za pomocą mikrosondy, luminoskopu i mikroskopu skanningowego, po metody komputerowej analizy subsydencji i modelowania procesów generacji węglowodorów. Badania architektury depozycyjnej opierały się na nowych koncepcjach stratygrafii dynamicznej, z uwzględniem hierarchii elementów depozycyjnych, przede wszystkim systemów zorganizowanych w cykle (sekwencje) różnego rzędu. Bogate wyniki naukowe projektu (por. skrótowy przegląd w: M. Narkiewicz, 1997) będą publikowane sukcesywnie. Niniejsze specjalne wydanie *Kwartalnika Geologicznego* jest pierwszą z serii publikacji w języku angielskim, poświęconych poszczególnym aspektom projektu.