

Hydrogeological structure of the Vistula River valley between Kamień and Puławy, eastern Poland

Stefan KRAJEWSKI and Małgorzata WOŹNICKA



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The monotonous and structurally uniform carbonate massif of Upper Cretaceous and Lower Palaeocene rocks in the western part of the Lublin Region is cut by river valleys significantly influencing the groundwater circulation system. The buried and contemporary river valleys, filled mainly with sand and gravel deposits, are influenced mainly by tectonic processes occurring in this region. The preglacial Vistula River valley between Kamień and Puławy constitutes a hydrogeological structure, the history of which is connected both with tectonics and with the influence of river waters. Its course has been determined by detailed hydrogeological exploration. Excellent hydrogeological parameters occurring within its limits cause high outputs from groundwater wells. There are also zones of increased water-bearing capacity within the carbonate massif. Their course, determined on the basis of analysis of the spatial distribution of hydrogeological parameters, coincides with sites of dislocation zones (zones of weakness in the rock massif).

Stefan Krajewski and Małgorzata Woźnicka, Faculty of Geology, University of Warsaw, Al. Żwirki i Wigury 93, PL-02-089 Warszawa, e-mail: skrajew@geo.uw.edu.pl, margosia@geo.uw.edu.pl (received: January 4, 2002; accepted: November 27, 2002).

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INTRODUCTION

River valleys provide a differentiation of hydrogeological conditions in the mostly structurally monotonous, fractured Upper Cretaceous and marginally, Lower Palaeocene carbonate massif in the Lublin Region. A special role in this respect is played by the Vistula River valley between Kamień and Puławy, together with the complex history of tectonic processes which influenced its course. The locally intercrossing network of buried and contemporary valleys influences the distribution of hydrogeological structures characterised by a high capacity of groundwater resources. This concerns both buried valleys filled with sand and gravel deposits and zones of weakness in the carbonate rocks relating to their tectonic structure.

Recognition of those structures is the result of detailed hydrogeological exploration carried out in the 1950's and 1960's (Krajewski, unpubl.). The information was supplemented with exploratory drillings in 1954 for a planned surface water reservoir on the Vistula near Kazimierz Dolny, and also (concerning the zone of increased fissuring accompanying discontinuous dislocations) with later geophysical research and interpretation of satellite pictures.

The explanation of the character of groundwater circulation, both in the carbonate massif, and in the Quaternary succession, is of utmost importance not only theoretically but also for practical reasons (assessment of water resources, location of sizeable groundwater wells, contaminant transport, design of surface water reservoirs).

TECTONICS OF CARBONATE FORMATIONS

The main groundwater environment in the western part of the Lublin Upland is constituted by carbonate rocks consisting of carbonates, quartz, and clay minerals. The proportions of these components determine the physico-mechanical properties of the rocks, and also they influence the susceptibility to fissuring and maintain their patency, and hence the hydrogeological conditions.

The results of research into the tectonics of this part of the Lublin Upland were published in the mid-fifties (Żelichowski, 1972; Krassowska, 1977; Wyrwicka, 1977, 1980). A model of tectonics was published by Pożaryski (1964, 1997), which placed the area explored within the marginal placoid syncline, cut with discontinued dislocations during the Laramide phase

and also during the Tertiary (Miłaczewski and Żelichowski, 1970). A number of NE–SW faults were distinguished, emphasising the block character of the geological structure. Detailed recognition of the discontinuous tectonics of the carbonate massif is difficult due to monotonous lithology, lack of correlation levels, and a Quaternary cover. Good results have been achieved by means of geophysical exploration, interpretation of satellite pictures, and teledetection (Wilczyński, 1980; Doktor and Wilczyński, 1981; Jezierski, 1985; Jaroszewski and Piątkowska, 1988; Krynicki, 1995; Doktor and Graniczny, 1995; Krynicki and Galemba, 1996). Interesting results may also be obtained by hydrogeological data analysis. “Anomalies” in the spatial image of hydrogeological parameters indicate, for instance, occurrences of tectonic dislocations in the subsoil (Krajewski, 1965, 1970, 1972; Herbich, 1980; Zwierzchowski, 1989; Woźnicka, 2001), accompanied by increased fissuring.

ROCK PROPERTIES WITHIN THE CARBONATE MASSIF

The most prevalent carbonate lithologies are siliceous marls, marls and chalks. These rocks are characterised by high total porosity. According to Olszewski (1998), the porosity average value is 42.5–49.8%, and the average intrinsic permeability is about 10^{-3} mD. The value of the hydraulic conductivity has been calculated as *ca.* 10^{-11} m/s for matrix porosity. This indicates that, under natural conditions, the unfissured rock is aquifuge (Krajewski, 1970, 1984).

The size and character of the micropores causes only fixed water to be present in the rocks, while the high porosity promotes diffusion processes in the groundwater. Only a few percent of the total open matrix porosity in the saturated zone contains water in hydraulic contact with groundwater in the fissure network of the rock massif, and yielding to gravitation forces. Active water storage capacity is created by joining fissures and interbank joints, and fissures connected with dislocation zones i.e. jog and near-jog (White, 1969; Krajewski, 1970, 1984; Headwoth *et al.*, 1982; Zuber and Motyka, 1994; Krajewski and Motyka, 1999).

FISSURING AND GROUNDWATER CIRCULATION SYSTEM IN CARBONATE STRUCTURES

Fissuring of the carbonate rocks has been evaluated using measurements of fissures in bassets in the Chodelka River valley and the Vistula River valley scarp. In the 1960's tests were performed, mainly in quarries, a few to hundreds of square metres in area, and a few to twenty metres deep. Fissure measurements were collected in 123 excavations (over 400 read-outs). Some of the excavation walls were even and locally polished, representing fault planes. Walls oriented within the range of 110–130°, so strike-parallel (Pożaryski, 1964) are accompanied by approximately perpendicular walls (10–40°). Most are vertical planes. The inclination of other walls ranges from 76–86°, while fissure openings range from millimetres to

over 30 cm. The widest are normally filled with locally undrained breccia and some with drift deposits. Interbank joints are most often 1 cm thick. The surveys indicate that the characteristic feature of the area explored is the occurrence of numerous small-scale faults.

DISCONTINUOUS TECTONIC STRUCTURES IN RELATION TO THE COURSE OF HYDROGEOLOGICAL STRUCTURES

Pożaryski (1938) drew attention to the relation of valley orientation to discontinuous tectonics in the western part of the Lublin Upland. The tectonic control of the Vistula, and its tributary Chodelka, as well as of other valleys within the carbonate massif of this part of Lublin Upland were noted also by Krajewski (1964, unpubl.).

Fractured zones include a NW–SE line (Karczmiska–Dobre) along the northern edge of Chodelska Valley, and one perpendicular to it (Podgórz–Kazimierz Dolny) along the contemporary Vistula Valley. These are the zones of enhanced groundwater flow determined in 1960–64 by measurement of hydrogeological parameters (Krajewski, unpubl.). These analyses suggest that these zones coincide with discontinuous dislocations. Subsequently the course of the first one has been confirmed by geophysical methods, and the course of the other (Podgórz–Kazimierz Dolny) coincides with the extension of a fault on the western Vistula bank in the Chotcza region (Fig. 1). Fractured zones were also defined in the region of Puławy on the eastern side of the Vistula, and along the western Vistula (running NW–SE), and also near Opole Lubelskie (NE–SW), and in the Solec Region (NNW–SSE). The last two coincide with lines determined by geophysical research and remote sensing.

A special type of structure related to regional tectonics modified by river action is the Vistula preglacial river valley between Kazimierz and Puławy. Its course is determined by discontinuities along the base of carbonate units which coincide with the courses of faults determined using geophysical and remote sensing data (Fig. 1).

After splitting from the contemporary Vistula River valley in the vicinity of Kamień, the preglacial valley runs in a NE direction, turns sharply towards the NW, crosses the Vistula, goes around Janowiec from the west, changes direction towards the NE and before Puławy cuts the Vistula again. Moreover the preglacial valley branches near Braciejowice (in a NW direction), crosses the Vistula by Chotcza, and on its western side runs in a NE direction, merging with the eastern branch. The preglacial valley, over 20 m deep along the majority of its course, in its axial part reaches a depth of nearly 40 m. It is filled with sandy-gravel deposits, while in the lower part there are gravels of up to 20 m thick, with sandy deposits above (Fig. 2).

The preglacial river valley is a richly water-bearing structure providing constant supply. This is favoured by good water flow conditions, the vast water-bearing zone, and supply from:

— atmospheric precipitation (flat area with permeable surface deposits);

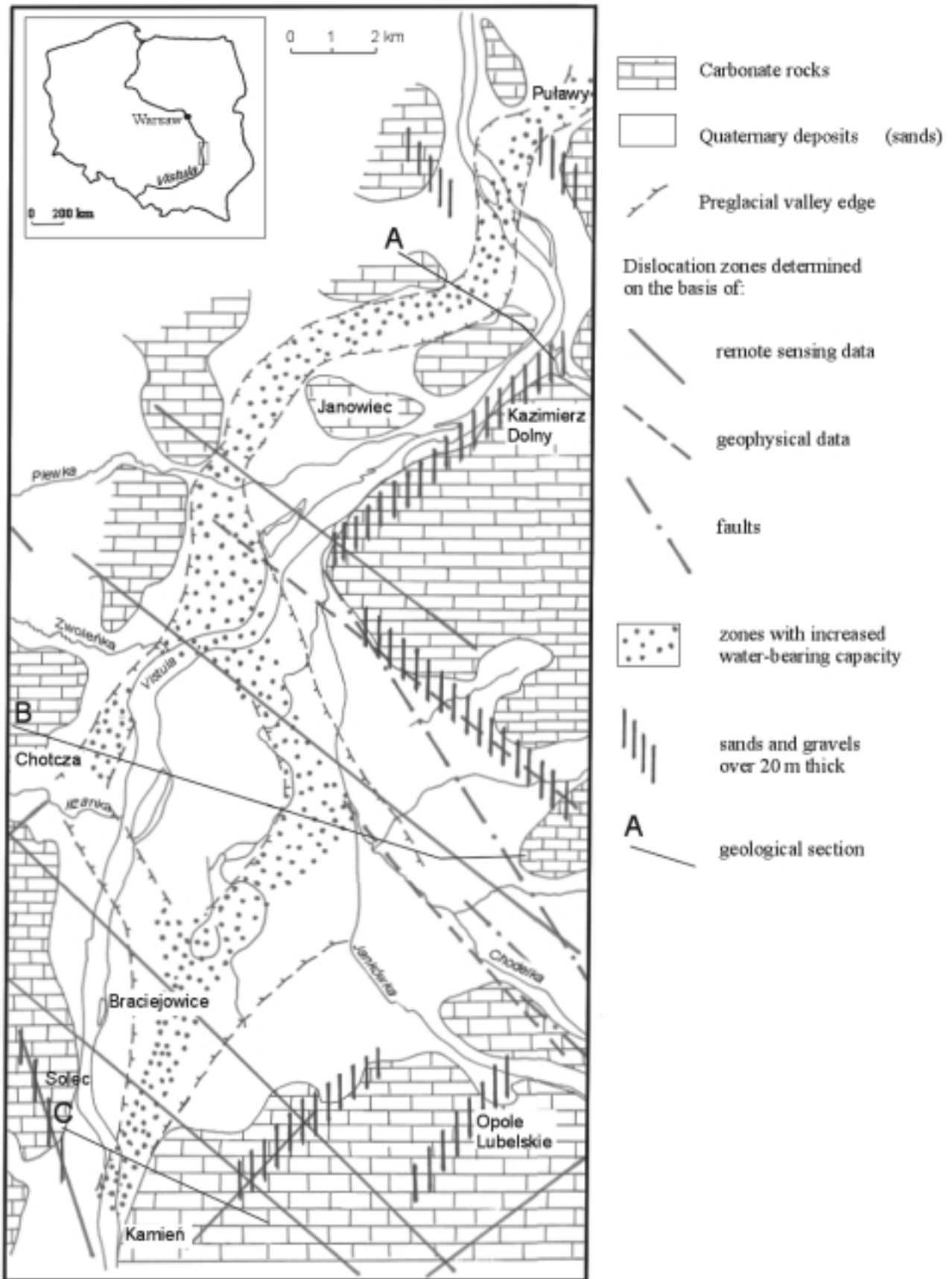


Fig. 1. Hydrogeological structure of the Vistula River valley versus dislocation zones

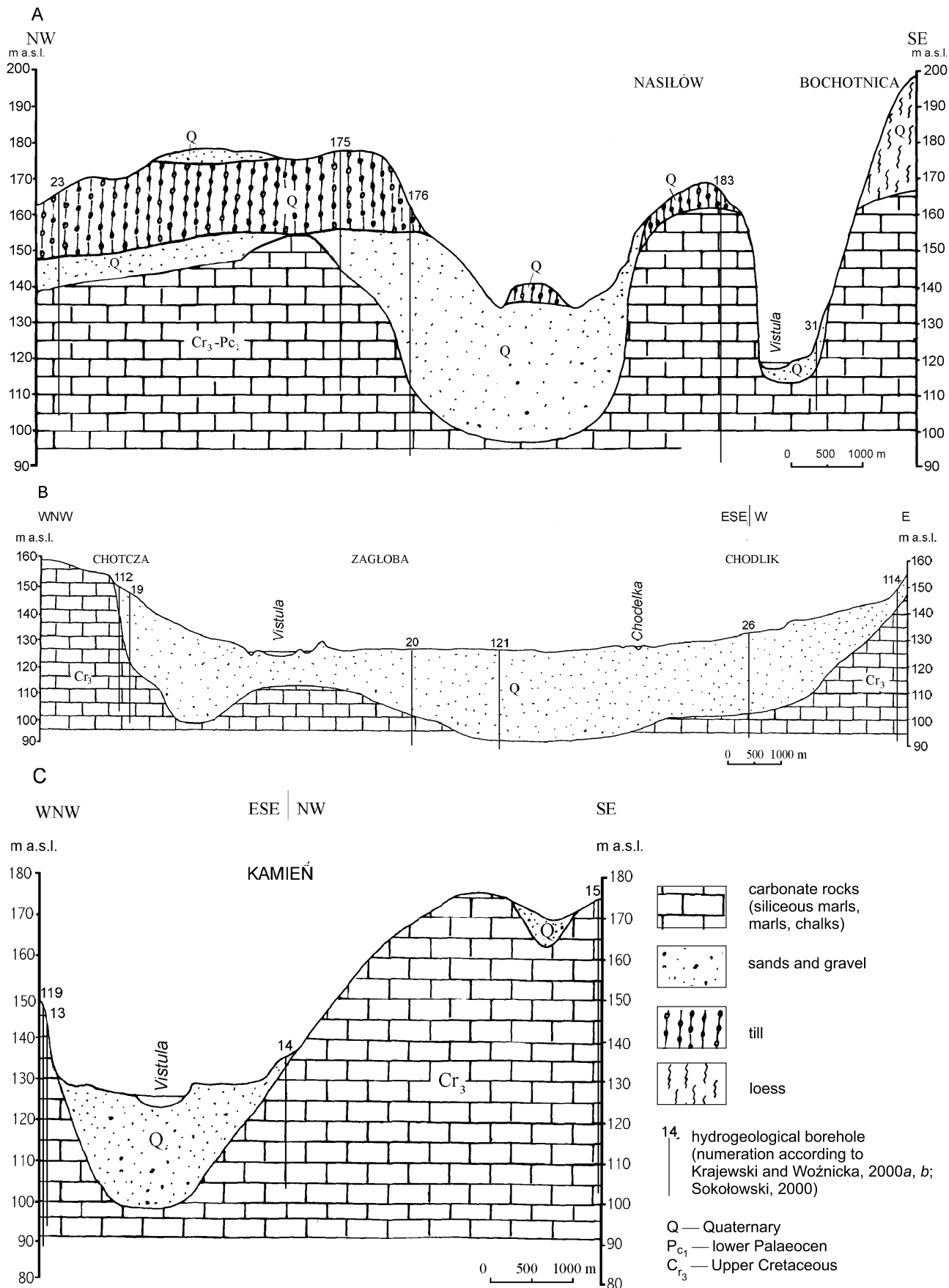


Fig. 2. Geological sections cutting the present and preglacial valleys of the Vistula

- infiltration of Chodelka River and its tributaries, and seasonally also the Vistula River surface waters;
- inflow from Cretaceous rocks to the north and south;
- inflow from the Chodelka River preglacial valley derived from Quaternary deposits to the east.

The main groundwater flow is towards and parallel to the Vistula, hence in the NW–NE directions. Potential capacities of groundwater wells within the structure may be determined from well specific discharges, which most often reach up to 20 m³/h × m. A significant feature of the capacity is their constant rate, backed-up with excellent feeding conditions. Their average yield is 24.9 m³/h × m.

Hydrogeological structures constituting carbonate massif fracture zones are characterised by very favourable conditions of groundwater flow, contributing to their very high groundwater well output. Currently, specific discharges of wells are in the range of 13–29 m³/h × m, locally reaching up to 52 m³/h × m. The average value is 20.7 m³/h × m, while in generally fissured carbonate massif in this area values of 0.72–7.2 m³/h × m are obtained (4.1 m³/h × m on average). These values, defined on the basis of results of trial pumping require monitoring during exploitation, because high consumption occasionally leads to draw down of groundwaters from areas beyond the limits of this structure, where flow conditions are much less favourable.

Comparing the yield of groundwater wells within the limits of this structure the Quaternary deposits of preglacial river valley structure groundwater wells are found to have more favourable exploitation conditions: their output is lower, but more stable than that of wells in the carbonate structures within the zone of increased fissuring. The widely held opinion (Jeziński, 1985), that in the Lublin Region groundwater wells in river valleys are more prospective than those in the upland, requires verification. High output wells are only those located within edge zones of river valleys (Fig. 3). Within the valleys where fissured rocks occur at depths to 20 m, well yields are much lower.

CONCLUSIONS

1. The Vistula River valley between Kamień and Puławy is a distinct hydrogeological structure in the carbonate massif of the Lublin Upland. Its course has been determined by a complex interplay of tectonic processes and glacial activity.

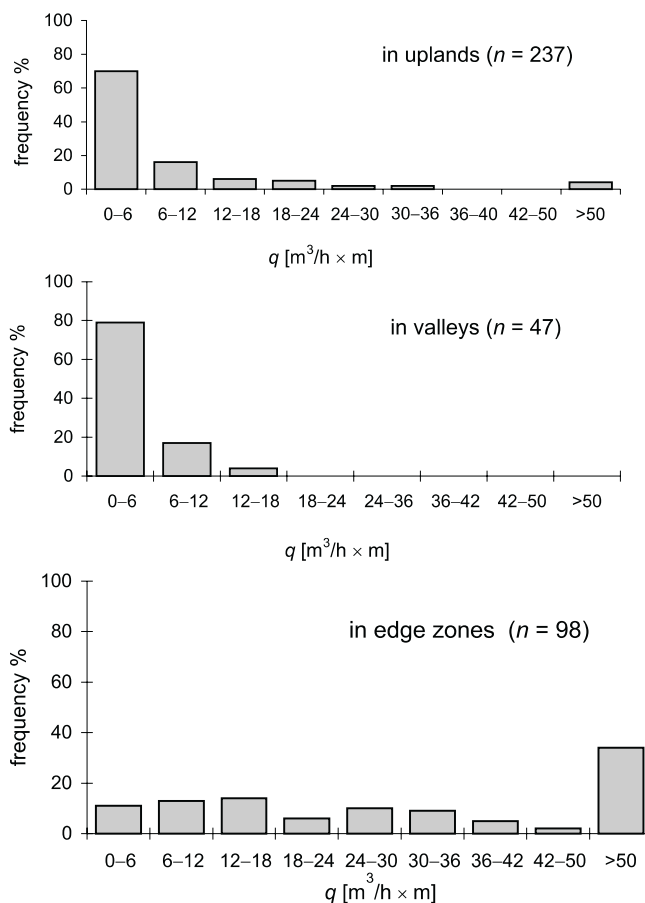


Fig. 3. Histograms of the distribution of specific discharges from wells according to location

2. Within the limits of the preglacial Vistula River valley there are high hydrogeological parameters, caused by rich back-up supply and constant inflow from Cretaceous and Quaternary deposits.

3. Zones of more highly fissured carbonate massif related to dislocation zones are also present. They are characterised by very favourable conditions of groundwater flow. The groundwater wells located within these zones have in general very high outputs.

4. The highest output groundwater wells occur along the edge zones of river valleys.

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