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Preliminary list of the Quaternary geosites in Northern and Central Poland, their age and geological position

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A b s t r a c t. On the basis of geological and geomorphological investigations performed in Northern and Central Poland a preliminary selection of internationally significant Quaternary geosites (exposures, landforms, and erratic boulders) was done. Totally selected fifteen exposures, landforms, and erratic boulders represent the considerable values with regard to geological and geomorphological features as well as a high scientific values and good sightseeing accessibility. All presented geosites are grouped within extents of the Vistulian (Weichselian) and Middle Polish (Saale) glaciations. Recently, within of the Polish Lowland area there are 12 nature reserves, about 1000 inanimate nature monuments (mainly erratic boulders and 43 other monuments) and 5 documentary sites.

Key words: geoconservation, network of European geosites, Quaternary deposits and landforms, Northern and Central Poland.

Andrzej Ber (1999) — **Wstępna lista czwartorzędowych geostanowisk w Polsce północnej i środkowej, ich wiek i pozycja geologiczna.** *Polish Geological Institute Special Papers,* 2: 77–86

S t r e s z c z e n i e. Na podstawie badań geologicznych i geomorfologicznych prowadzonych w Polsce północnej i środkowej, zestawiono wstępną listę czwartorzędowych, geologicznych pomników przyrody o międzynarodowym znaczeniu. Na przedstawionej, wstępnej liście znalazło się 15 bszarów (odsłonięcia, obszary z formami rzeźby i głazy narzutowe) reprezentujących, wodniesieniu do charakterystyki geologicznej i geomorfologicznej, wysokie wartości naukowe i dydaktyczne. Wszystkie geostanowiska występują w obrębie zasięgu zlodowaceń wisły (Weichselian) i warty (Saale). Obecnie na Niżu Polskim znajduje się 12 rezerwatów przyrody, około 1000 pomników przyrody nieożywionej i 5 stanowisk dokumentacyjnych.

Słowa kluczowe: geoochrona, sieć europejskich geostanowisk, utwory i formy rzeźby czwartorzędowe, Polska północna i środkowa.

Areas of Northern and Central Poland are situated within the Polish Lowland, which forms a predominating part of the country. The Polish Lowland, according to Mojski (1977, 1985), can be divided into six regions: the Podlasie, South-Mazovia, North-Mazovia, Kujawy–Pomerania, Wielkopolska and Pomerania, varying in genesis, age and thickness of the Quaternary deposits.

The preliminary selected Quaternary geosites are irregularly located mostly within the Podlasie, North-Mazovian and Pomeranian, and partly within the South-Mazovian, Kujawy–Pomeranian and Wielkopolska regions. The whole Polish Lowland area is built of Quaternary deposits of glacial, fluvioglacial, ice-dammed, aeolian, periglacial, weathering, fluvial and lacustrine origin. In the northern part of Poland the thickness of the complex of Quaternary deposits exceeds 200 m (locally to 300 m), whereas in Central Poland it ranges from 50 to 80 metres.

Stratigraphy of the Pleistocene deposits in Northern and Central Poland was established on the basis of the boreholes profiles, palaeobotanical analyses and lithologic-petrographical investigations. In Northern and Central Poland there are 8 to 11 glacial horizons of the Narevian (Menapian), Nidanian, Sanian 1 (Elsterian 1), Sanian 2 (Elsterian 2), Liwiecian (Fühne), Odranian (Drenthe), Wartanian (Warthe) and Vistulian (Weichselian) glaciations. On the other hand there are organic sediments of the Augustovian, Ferdynandovian, Mazovian (Holstein), Zbójno (Dömnitz) and Eemian Interglacial.

The area in question consists of two types of landscapes: flat and gently sloping surfaces in the south within territories which were occupied by the Middle Polish Glaciation (Saale), and flat (outwash plains), undulated and hummocky surfaces of the end-moraines, kames and eskers in the north, cut through by subglacial channels and lakes, within the limits of the Vistulian (Weichselian) Glaciation (Kozarski, 1995).

All the presented geosites: exposures, landforms and erratic boulders occur within the extents of both the above mentioned glaciations (**Fig. 1**). At present, in the Polish Lowland there are 12 nature reserves, about 1000 inanimate nature monuments (mainly erratic boulders and 43 other monuments) and 5 documentary sites.

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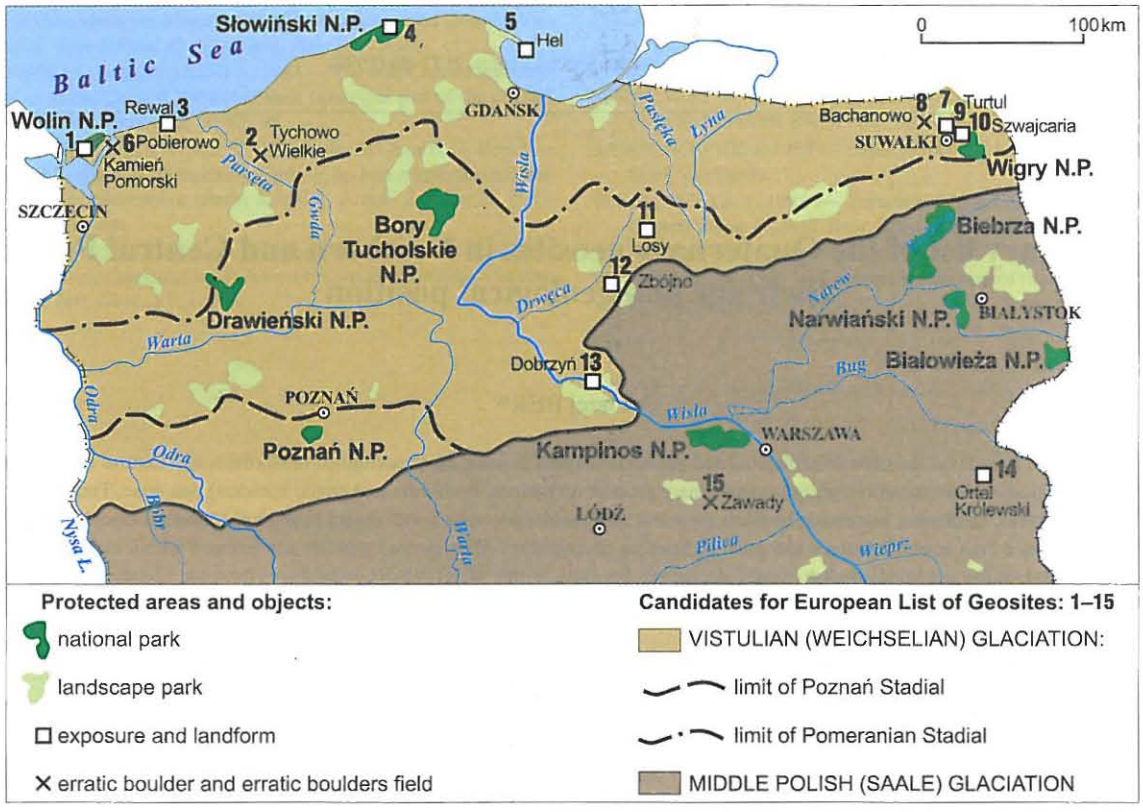

Fig.1. Distribution of the selected important geosites and areas in Northern and Central Poland

Preliminary selected Quaternary geosites

On the basis of geological mapping, conducted for *Detailed Geological Map of Poland* in scale 1 : 50,000, and published description (Alexandrowicz *et al.*, 1992) a preliminary selection of European significant Quaternary geosites in Northern and Central Poland was made.

The preliminary selected geosites are represented as (Fig. 1):

— the geological sites (exposures), mainly geological monuments, of high scientific and landscape values, as well as good sightseeing accessibility;

— the geological or geomorphologic areas with terrain forms, mainly national parks or landscape parks of a high scientific value, as well as good sightseeing accessibility;

— the single glacial and fluvioglacial landforms, mainly geological monuments, of a high scientific values, as well as good sightseeing accessibility;

— the erratic boulders of a size above 20.0 metres in perimeter and of high scientific (petrographic) values.

The 3 geosites are entirely selected on the basis of 50 suggestions presented by Z. Alexandrowicz, J. Badura, D. Krzyszkowski, R. Dobracki, A. Ber, T. Krzywicki, J. E. Mojski, A. Piotrowski, S. Skompski, L. Marks and B. Przybylski.

1. Wolin Island in the western part of the Baltic Sea coast (1.0–115 m a.s.l.; 53°50'00"N/14°25'00"E).

Main features: cliff coast, tills of the Middle Polish and Vistulian glaciations age, glacifluvial and aeolian sands, fossil soils horizons, glacitectonic deformations, rafts of Cretaceous deposits in the moraine.

Wolin Island is situated within the limits of the youngest, Vistulian (Weichselian) Glaciation, in the sublitoral zone of the Pomorze Bay. The ridge of a terminal moraine (115 m a.s.l.) connected with the latest phase of the last glaciation is the main element of the relief. It is bordered with a high cliff. A few huge blocks of Cretaceous deposits (chalk, opoka, marl) abounding in foraminifera occur within the moraine and outcrop in the old quarries series and in the cliff. (Alexandrowicz, 1966). These blocks were transported as rafts by the last ice- sheet from the bottom of the Baltic Sea. Active abrasion and accumulation processes can be observed along the sea shore. The 11.7 km long Wolin cliffs form the most beautiful part of the Baltic Sea coast and the Wolin National Park. Till cliff sections are built of two series of till: brown Vistulian till and grey Middle Polish till.

Overlying the till series are glacifluvial sands and aeolian covers separated by two horizons of fossil soils (Borówka *et al.*, 1986). The oldest cover of the sand series lies on a shear plane represented by a residual pavement. In the cliff coast sections with a sandy structure the sand-gravel series reaches a thickness of up to 40 m. The top part of the fluvioglacial sand-gravel series comprises aeolian sand covers with fossil soil horizons (Kostrzewski & Zwoliński, 1995).

Wolin Island is protected as the Wolin National Park (10,937.4 ha). This area comprises a very valuable complex of geosites with a good sightseeing accessibility.

2. Trygław erratic boulder in the north-eastern part of Poland, near Tychowo Wielkie village (100 m a.s.l.; 53°56'N/16°15'E).

Main feature: the largest erratic boulder in Poland.

The boulder is situated within the limits of the youngest, Vistulian (Weichselian) Glaciation. The Trygław erratic boulder represents a dark-grey Scandinavian paragneiss rock of a size about 700 m^3 in volume, 50.0 metres in perimeter and 3.8 meters in height (Fig. 2).

The boulder was transported from Scandinavia to Poland by the latest Scandinavian–Vistulian (Weichselian) ice-sheet (the glacial scratches on the surface) probably from the vicinity of Vidbo or Uppsala (Sweden) and is the largest erratic boulder in Poland.

The Trygław erratic boulder is protected as an inanimate nature monument of a high scientific values and well-accessible to sightseeing.

Fig. 2. Trygław — the largest erratic boulder in Poland. Photo by E. Dobracka

3. Pobierowo–Trzęsacz–Śliwin cliffs — in the western part of the Polish Baltic Sea coast (1.0–20 m a.s.l.; 54°05'15"N/15°01'30"E).

Main features: tills of the Middle Polish (Saale) and Vistulian (Weichselian) glaciations age; radiocarbon data, rafts of Cretaceous claystones, glacitectonic disturbances, coastal landscape.

The cliffs are situated within the limits of the youngest, Vistulian (Weichselian) Glaciation. In the Rewal cliff profile two complexes of glacial drift can be distinguished (Dobracka, 1983; Dobracka & Ruszała, 1988; Dobracki & Racinowski, 1989). The older complex comes from the Warta Glaciation and the younger from the Vistulian one. The two glacial horizons are separated by a series of glacifluvial and glacilimnic deposits. The bottom of the till of the last glaciation is generally situated at the present sea level (Dobracka & Ruszała, 1988). Contemporary processes of marine erosion, reinforced by degradation due to mass movements, have produced a cliff coast at the northern margin of the plateau abraded along its whole length (5.5 km); they are also responsible for the constant shrinking area of this residual (Dobracka, 1995; Dobracka & Dobracki, 1995).

The Rewal cliff presents an interesting profile of glacial drift of the last glaciation and of the postglacial deposits. At the foot of the cliff grey and brown-grey subglacial tills can be found whose heavily eroded tops are at elevations of between 3 and 7 m a.s.l. (Dobracka & Ruszała, 1988). The tills are not homogeneous, but contain numerous intercalations of sands, silts and clays as well as rafts of substratum rock (the Cretaceous claystones at Śliwin). Above them lies the series of glacifluvial and glacilimnic sand deposits whose thickness varies between 4–5 m near Niechorze to less than 20 cm in the Rewal and Trzęsacz profiles. These deposits are covered with brown and rust-colo-ured supraglacial (melt-out plus flow) till of a very high content of sand, turning to loamy sand at the top (the ablation cover). Above the top of the glacial series, in local depressions without outlets (Niechorze and Śliwin), there are lacustrine and organic deposits dated by the radiocarbon method at between 12,900 and 2,760 BP (Kopczyńska-Lamparska *et al.*, 1984), as well as aeolian deposits with a fossil soil horizon (750 years BP). The cliff coast along the Niechorze–Trzęsacz section attains a height of up to 17 m a.s.l. The intensity of the corrosion varies from place to place. Apart from the abrading effect of the sea, mass-movements are the main destructive agent. They are facilitated by the geological structure of the cliff (Dobracka, 1995; Dobracka & Dobracki, 1995).

In the 17 m high and 1 km long Śliwin coastal cliff section (Fig. 3), five (I–V) lithological types of till have been distinguished, together with a glacifluvial series separating the two lower till units from the remaining sequence. All the till types were generated under subglacial conditions and are characterized by predominance of northern (Palaeozoic) limestones over crystalline rocks. Because of the above they are classified as tills of the Vistulian Glaciation (Dobracka, 1995; Dobracka & Dobracki, 1995).

The described above cliffs, except of their scientific values, present the most spectacular high coastal landscape. The Pobierowo–Trzęsacz–Rewal–Śliwin cliffs are protected as monuments of inanimate nature.

Fig. 3. Śliwin cliff — sequence of tills of the Middle Polish and Vistulianglaciations. Erratic boulder in the bottom. Photo by R. Dobracki

4. Łeba Barrier on the Polish Middle Coast (10–30 m a.s.l.; 54°50'00"N/17°20'00"E).

Main features: barrier-lagoon coast, active coastal sand dunes, Holocene peats, lakes.

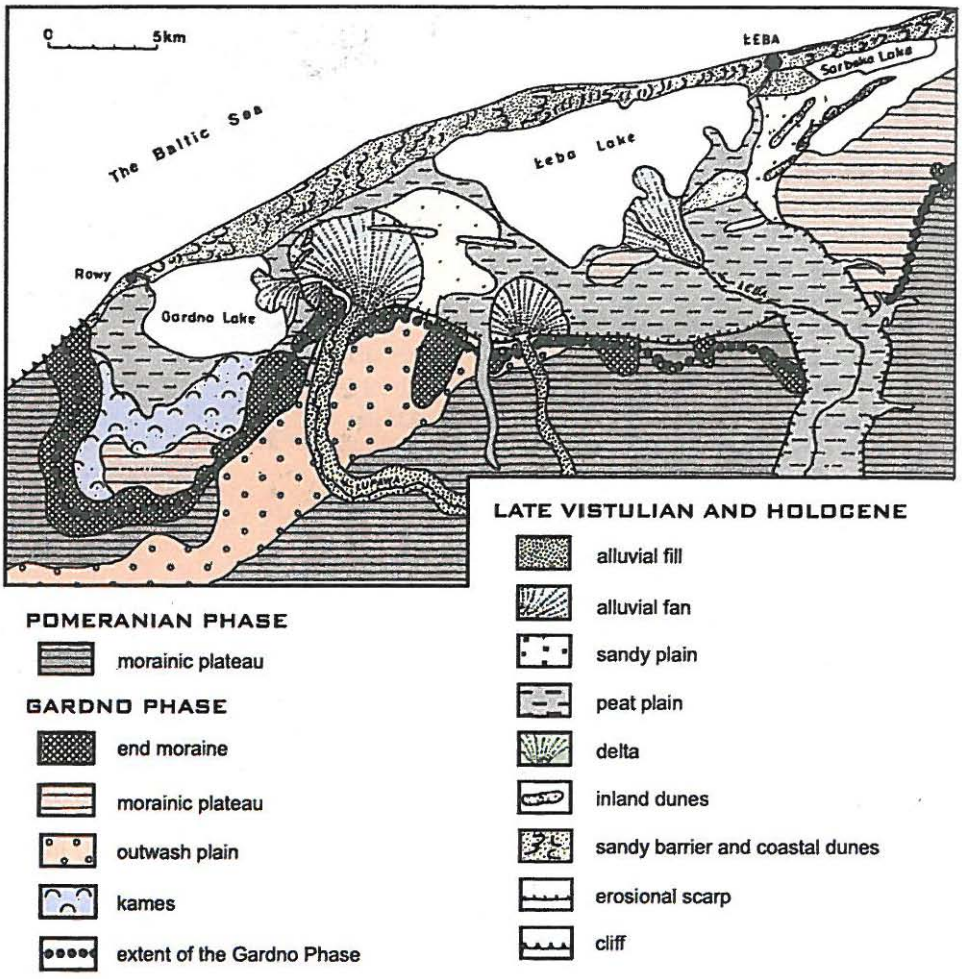

Fig. 4. Słowiński National Park — geomorphological map of the coastal plain (after Rotnicki, 1995)

This area representing a complex of geosites is situated within the limits of the youngest, Vistulian (Weichselian) Glaciation. A characteristic dunes landscape occurs within so-called Łeba elevation, i.e. a geological-tectonic unit which is a part of the East-European Platform. The thickness of Quaternary deposits exceeds 200 m in some places and reaches the maximum of 264 m. In this area located within so-called Łeba Barrier the Quaternary stratigraphy is relatively poorly known. Tertiary deposits form the substratum of the Pleistocene sediments and are overlain with two beds of glacial till, the latter being associated with fluvioglacial and ice-dammed lake deposits. The beds are separated from each other by a thick (about 50 m) series of fluvial deposits which are thought to be connected with the Pilica Interstadial. The last deposits represent the Vistulian (Weichselian) Glaciation as indicated by radiocarbon dating, and include sediments and landforms of the Leszno Phase, Poznań Phase, Pomeranian Phase, Gardno Phase and South Baltic Phase (Fig. 4). The Łeba Barrier with Łeba dune field within the Słowiński National Park is an area where intensive aeolian processes took place in the Younger Holocene. Their products are barchans, barchan-crescent dunes, elliptic and parabolic crescent dunes, groups of fore-dunes occurring exclusively in the narrow zone behind the beach, and abundant slacks and deflation hollows. In the middle part of the Łeba Barrier, spread over an area of about 5.5 km^2 almost completely devoid of any plant cover, there are 9 complex barchan-like forms moving quickly eastwards. These dunes attain a relative height of 20 to 40 m, and among them are deflation hollows sometimes filled with ephemeral pond-like lakes appearing during high storm surges (Borówka, 1995b; Rotnicki, 1995).

The whole area of the Łeba barrier is situated within the Słowiński National Park. It is one of the countrys most memorable natural landscape. This area of site-sets presents also high scientific values and good sightseeing accessibility.

5. Hel Peninsula in eastern part of the Polish coast (0–3.0 m a.s.l.; 54°16'00"N/18°30'00"E).

Main features: the peninsula, sequence of Holocene sediments, radiocarbon data.

This area is situated within the range of the youngest, Vistulian (Weichselian) Glaciation. The peninsula overlies an exceptionally thick sequence of over 100 m Holocene deposits (Fig. 5). The deeper substratum of the Hel Peninsula is formed by Mesozoic rocks. The Pleistocene is represented mainly by fluvial sands. Tills are restricted to a few non-continuous beds, making determination of their age rather difficult. In the eastern part of the peninsula the Holocene sequence is fully developed, reaching a thickness of 100 m. In the western part only a 10–12 m thick bed of marine deposits is found, resting on a thin biogenic, terrestrial bed from the Late Atlantic period (Tomczak, 1993, 1995).

Holocene deposits in the eastern part of the peninsula are subdivided on the basis of biostratigraphic and sedimentological investigations. Pre-Ancylus, Mastogloia, Littorina and Post-Littorina sediments have been identified (Tomczak *et al.*, 1990).

The evolution of the peninsula proceeded differently in its western and eastern parts. The western part is genetically terrestrial in origin, peat was formed on the land surface only 6900 a BP. This peat is now 8–11 m below mean sea level and has been radiocarbon dated at several sites. The land was inundated during the final stage of the Littorina transgression. Simultaneously, intensive accumulation took place during the whole Holocene in the eastern part of the peninsula. First freshwater and later marine sediments were transported by currents from the west and deposited on the western slope of the Gdańsk Deep.

Hel Peninsula took its present form about 1000 BP, when the sea level rose by about 1.5 m and reached its present height (Tomczak, 1993, 1995).

The Hel Peninsula is an important element of the Polish coastline, linking the subaerial and the subaquatic parts of the coastal zone. This area of the site-sets is protected as the Nadmorski Landscape Park.

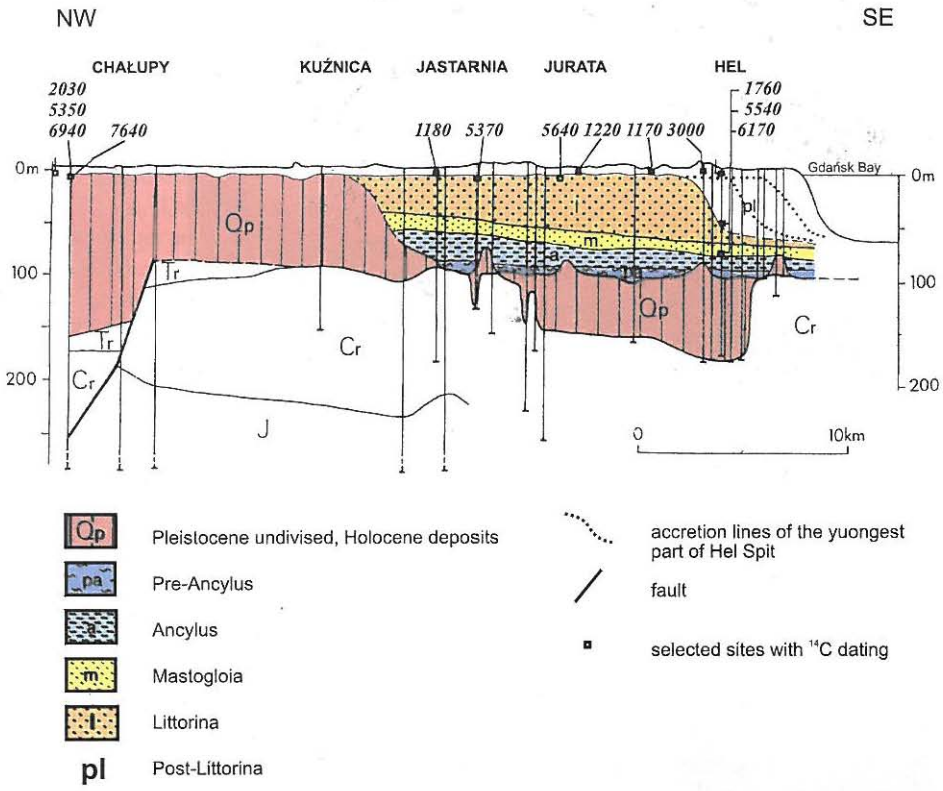

Fig. 5. Simplified geological cross-section along the Hel Spit (after Tomczak,1995)

6. Kamień Królewski (King Stone) erratic boulder — in north-western part of Poland, near Kamień Pomorski town, (800 m a.s.l.; 53°58'00"N/14°45'00"E).

Main features: the granite erratic.

The boulder is situated within the extent of the youngest, Vistulian (Weichselian) Glaciation. The Kamień Królewski erratic boulder represents a Scandinavian granite rock of a size of about 20.0 metres in perimeter and 3.5 metres in height. The boulder was transported from Scandinavia by the Vistulian (Weichselian) ice-sheet.

The King Stone is protected as an inanimate nature monument of a high scientific values and is an easily accessible object to sightseeing.

7. Zagłębienie Szeszupy (Szeszupa Depression) in north-eastern Poland, (135–230 m a.s.l.; 54°17'05"N/22°53'40"E).

Main features: end and push moraines, eskers, kames and kettle holes now occupied by lakes, hanged up peats.

This area of sites-sets is situated within the limits of the youngest, Vistulian (Weichselian) Glaciation. The Szeszupa Depression covers an area of about 50 km^2 and lies in the hinterland of the moraines of the Pomeranian Phase of the Vistulian Glaciation. In this region the thickness of Quaternary deposits is between 200–290 m. Detailed investigations of the Szeszupa depression have been carried out (Ber & Maksiak, 1969; Ber, 1974). It seems that this depression, similar to the near-by through of Hańcza, the deepest Polish lake (108.5 m), already existed by the end of the Warta (Saale) Glaciation. The depression was probably formed both by erosional and glacitectonic processes. Therefore, the ice-sheets of the Vistulian Glaciation entered the already lowered area, in which consolidated blocks of dead-ice remained longer than on the plateau. The area was incessantly ice-covered by the Vistulian ice-sheet throughout the entire Pomeranian Phase. During its retreat the ice-front must have stagnated for some time in the area of the southern edge of the Szeszupa Depression, and at the same time the position of the ice-front underwent some minor oscillations, which led to the formation of partly disturbed end moraine landforms, lying above the edge of the depression. The present beautiful landscape of the depression with its numerous hills and kettle holes was formed during the Holocene. Some of the kettle holes are now occupied by lakes (Ber & Krzywicki, 1995).

Besides the scientific values the Szeszupa Depression represents a most beautiful landscape in the north-eastern part of Poland (Fig. 6). The area is protected in the Suwałki Landscape Park which represents high scientific values as well as good sightseeing accessibility.

Fig. 6. Landscape of the Szeszupa Depression. Photo by A. Ber

Fig. 8. Ortel Królewski exposure of the Mazovian (Holstein) Interglacial deposites. Photo by S. Lisicki

8. Bachanowo erratic boulders field in north-eastern part of Poland, within the Suwalski Landscape Park (218–220 m a.s.l.; 54°16'00"N/22°49'00"E).

Main features: accumulation of the Scandinavian erratic boulders.

This area is situated within the extent of the youngest, Vistulian (Weichselian) Glaciation. The Bachanowo erratic boulders field comprises about 10,000 stones of mainly igneous and metamorphic rocks of the Scandinavian origin, mostly of about 0.5–3.0 m in diameter, and several boulders of about 6.0-8.7 m in diameter (Czernicka-Chodkowska, 1977).

This area is protected as a nature reserve (0.98 ha) and represents high scientific values and a very good sightseeing accessibility.

Fig. 7. Geologic section of the Szwajcaria near Suwałki Interglacial site. 1 — till of the Leszno–Pomeranian Stadial of the Vistulian Glaciation, 2 — silt and gyttja of the Eemian Interglacial, 3 — peat of the Eemian Interglacial. Photo by S. Lisicki

9. Oz Turtulski (Turtul esker) in north-eastern part of Poland (199–210 m a.s.l.; 54°15'00"E/22°50'00"E).

Main features: esker ridges and hills, glacial channel and fluvial valley.

The Turtul esker is situated within the limits of the youngest, Vistulian (Weichselian) Glaciation in the 4 km long, 150–250 m wide and 30 m deep, steep-sided (up to 35°), flat-floored Czarna Hańcza valley. The esker forms a range of hillocks and ridges extending over a distance of 3 km. The north-western part of the esker occurs within a somewhat shallower and broader section of the valley. Farther, the esker enters the narrower deeper and steeper-sided lower part of the Czarna Hańcza valley, that widens only in its terminal part, near its mouth, which being here barred by the dam of the Turtul mill is occupied by a pond. Two fragments of the esker appear in the described, shallower section of the valley. The first fragment is a small hill in which the transverse profile of the form is exposed. In this profile, beneath a thin, structurelless, gravelstony cover is a succession of muds, sands and gravels, both fine- and coarse-grained, exhibiting diagonal- and cross-stratification as well as an outward dip of the layers. The second fragment forms a 600 m long and 10 m high ridge composed of the deposits similarly bedded though underlying a thicker (2 m) structureless cover (mainly sand). The third component of the esker, situated at the valley-junction, is a short (180 m)

asymmetrical ridge consisting of somewhat coarser material (coarse limestone gravel interbedded with sands). The fourth component, a 300 m long ridge occurring already in the narrow, steep-sided part of the valley, shows largest dimensions, in the cross-section rising up to 18 m above river level. The mentioned fragment of the esker has the steepest slopes (ca 35°) and the most regular structure i.e., a diagonal, distal stratification of sands, with layers dipping toward the esker slopes. The ridge was found to contain some boulders, whose longer axes lie invariably parallel to its length. The fifth element consists of a lower ridge, equalling in dimensions element 2, only somewhat shorter. All other elements of the esker, which occur in the widening, terminal sector of the valley partly submerged by the pond, consist merely of small, elongated hills built of stratified gravels and sands (the last hill, by the mill, has been entirely worked out). None of these esker components is more than 50 m wide (Pietkiewicz, 1928, 1961, 1977).

The Turtul esker is protected as a nature reserve within the Suwalski Landscape Park and represents high scientific values and a good sightseeing accessibility.

10. Szwajcaria in north-eastern Poland, in vicinity of Suwałki town (192 m a.s.l.; 54°08'20"N/22°56'12"E).

Main features: the Eemian Interglacial organogenic lake sediments (gyttja, lake marl and silt), tills of the Vistulian (Weichselian) Glaciation.

The Szwajcaria site is situated within the extent of the youngest, Vistulian (Weichselian) Glaciation. The deposits of the Eemian Interglacial are unusually exposed on the ground surface in the loam pits of the old brickyard, 192 m a.s.l. (Borówko-Dłużakowa & Halicki, 1957; Ber, 1973).

Interglacial deposits are represented in the profile by a 3.5 m thick peat bed, a 30–40 cm thick gyttja and a 60 cm thick sequence of light-grey silt layers (Fig. 7). Palynological analysis of the peat gives a full picture of the floral succession of tundra, coniferous forest, leafy forest, and again coniferous forest flora of the Eemian Interglacial (Borówko-Dłużakowa & Halicki, 1957). The interglacial peat is underlain by the thick lower unit of glacial till and covered with 40 cm of gyttja and, in some places, of light-grey silt and clayey silt. The silts are in turn overlain by sandy, gravely and clayey till deposits of the Vistulian (Weichselian) Glaciation — of the Pomorze–Leszno Stadial (Ber, 1973, 1981).

The profile of the Eemian Interglacial sediments at Szwajcaria is the most important one for Pleistocene stratigraphy in the north-eastern part of Poland. The site is protected as a monument of an inanimate nature and represents high scientific values and a good sightseeing accessibility.

11. Losy in the central part of Northern Poland, near Lubawa town, (180 m a.s.l.; 53°32'00"N/19°45'00"E).

Main features: the Lubelski Interglacial organogenic lake sediments, thermoluminescence dating, Middle Polish Glaciation tills.

The proposed geosite is situated within the extent of the youngest, Vistulian (Weichselian) Glaciation. There are the organogenic lake sediments (gyttja, lake marl and silt), about 16.0 m thick, of the Lubelski Interglacial (older than Eemian) age. The upper part of the lake complex is noted in a large exposure. Underlying deposits are vary-grained sands and are dated by the thermoluminescence method at about 237,000 BP years. The overlying sediments are dated at 230,000 BP years. Based on the results of the palynologic analysis there are distinguished four main climatic-floristic interglacial periods and within them 12 pollen horizons (Krupiński & Marks, 1986).

The Losy site is an unusually significant outcrop of the interglacial sediments older than Eemian Interglacial. The site is protected as a geological monument and represents high scientific values.

12. Zbójno drumlin field in Central Poland (75–115 m a.s.l.; 19°08'00"E/53°01'00"N).

Main features: drumlins, glacitectonic structures.

The Zbójno drumlin field is situated within the extent of the youngest, Vistulian (Weichselian) Glaciation and is the largest in the Dobrzyń Moraine Plateau. It is located in a vast (17 x 6.5 km) depression on the moraine plateau, in hinterland of the Chrostkowo end moraines (of the Kuiavian Subphase, Vistulian Glaciation). The drumlin field occurs at 8–40 m below the surrounding plateau (104–115 m a.s.l.). In the northern part of the area, three drumlinization levels are distinguished: the lower one at 75–81 m a.s.l., the middle complex — 10 m high here. Varying azimuths of morphological axes, shapes and morphometric parameters but also a complex geological structure are typical of the drumlins in Zbójno (Liberacki, 1961). Glacitectonic-depositional, glacideformation-depositional and glacioerosive-depositional drumlins predominate. In the vicinity of Zbójenko their cores contain deformed glacifluvial or glacilacustrine sediments, mantled with a deformation-depositional till cover. Glacial sediments form one to two or three sedimentary till beds that belong to one or two different glacial advances (Olszewski, 1995).

The Zbójno drumlin field is an outstanding landform and simultaneously offers a beautiful view, high scientific values and good sightseeing accessibility.

13. The Vistula river bank in Dobrzyń — in Central Poland, north of Płock town, (100 m a.s.l.; 19°42'00"E/52°39'00"N).

Main features: the high valley slope, glacitectonicaly deformed Tertiary substratum, reduced profile of the Pleistocene sediments, landslides.

The Dobrzyń exposure is situated within the extent of the Vistulian (Weichselian) Glaciation. Neogene sediments in the vicinity of Dobrzyń were investigated for over 200 years. They occur on the steep right bank of the Vistula river in Dobrzyń. In a cross-section, under a rather thin cover of Quaternary deposits, Pliocene clays and silts, Miocene silts, clays and sands intercalated with brown-coal occur. The origin and age of disturbances were often discussed. Views on the origin of disturbances can be divided into two groups: (1) a tectonic shake (Łyczewska, 1959, 1964) which generated sediment flowage in the Neogene basin, and (2) glacitectonic folding caused by the glacier flow from NE (Skompski, 1969) or from NW, along the Vistula valley (Brykczyński, 1982). There is an extensive literature on

the Quaternary and Neogene stratigraphy. Stratigraphy of the Quaternary sediments in Dobrzyń was discussed by Łyczewska (1959), Jaroszewski (1961, 1963) and Ber (1968), and its wide background in some other papers (Skompski, 1969, Lamparski, 1983) and in *Explanation to the Detailed Geological Map of Poland 1 : 50,000*, sheets: Włocławek, (Mojski, 1970), Płock (Skompski, Słowański, 1970), Dobrzyń (Skompski, 1972). Stratigraphy of Tertiary sediments and details of glacitectonic structures are presented in papers by Łyczewska (1959, 1964), Brykczyński (1982), Skompski (1995).

The Dobrzyń site is a significant example of the Pleistocene stratigraphy and glacitectonic deformations. The site of Dobrzyń in the Vistula valley is newly selected.

14. Ortel Królewski in south-eastern Poland (142 ma.s.l.; 52°00'00"N/23°30'00"E).

Main features: Mazovian (Holstein) Interglacial deposits with fauna.

The site represents the exposure with fauna (molluscs, snails and ostracoda) of the Mazovian (Holstein) Interglacial age and is located in the older glacial area of the Middle Polish (Saale) Glaciation. The sediments with fauna (clayey sand and sandy silt) are 7.0 m thick (**Fig. 8**) but their spread is limited to a narrow belt, about 50–100 m wide, running along the valley slope. In the exposure there are 25 molluscs and 22 ostracods species. The shells amount to 70% of the mentioned above sediment. The most important for stratigraphical purposes are two species of the snails: *Viviparus diluvianus* and *Lithoglyphus jahni* (Albrycht, 1995, Albrycht *et al.*, 1995).

The Ortel Królewski site is an exceptionally significant place of the Holsteinian fauna accumulation. The locality is newly selected and protected as a geological monument representing high scientific values. There is also a good sightseeing accessibility.

15. Głaz Mszczonowski (Mszczonów erratic boulder) in Central Poland in Zawady village, near Mszczonów town, (202 m a.s.l. ; 51°56'00"N/20°28'00"E).

Main features: large erratic boulder.

The boulder is situated within the older glacial area of the Middle Polish (Saale) Glaciation and represents a siltstone rock probably of the Lower Miocene age. The size of the boulder is 36.0 metres in perimeter and 3.0 metres in height. The surface of the erratic boulder is glacially polished. The boulder was transported by the Middle Polish (Saale) Scandinavian ice-sheet.

The boulder is protected as an inanimate nature monument of high scientific values and is easily accessible to sightseeing.

Conclusion

The Quaternary geosites have been selected for the European list. Fifteen objects represent considerable values with regard to geological and geomorphological features. These selected geosites are found in the Polish Lowland area, whose deposits and forms are connected with the Middle Polish (Saale) and Vistulian (Weichselian) Scandinavian ice-sheets. In majority, the preliminary selected Quaternary geosites are located either inside the national parks (3), or landscape parks or in the areas of protected landscape (4). Five of them are protected as geological monuments and nature reserves.

Presented above, preliminary list of the European significant Quaternary geosites in Northern and Central Poland is not closed and will be continuously improved as well as in fully documented during the year of 1999.

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