

**Elżbieta Kobojek\***

# **1. THE EVOLUTION OF VIEWS REGARDING THE ORIGIN OF THE RELIEF OF CENTRAL POLAND**

## **1.1. Introduction**

The area surrounding Łódź, even though located in Central Poland, has remained understudied in terms of geology and geomorphology for many years. This was a result of two factors. First of all, no geological research was conducted in the area in the first half of the 20<sup>th</sup> century because of its low appeal in terms of natural resources, at least according to the state of knowledge at that time. Secondly, the city was not a university centre and the surrounding area remained outside the field of interest for academic research. Only after the foundation of the Chair of Geography within the University of Łódź, did the situation change. Initially, geomorphology was the main field of Łódź research. Its main goal was to study geological composition and relief of the region and to explain their origin.

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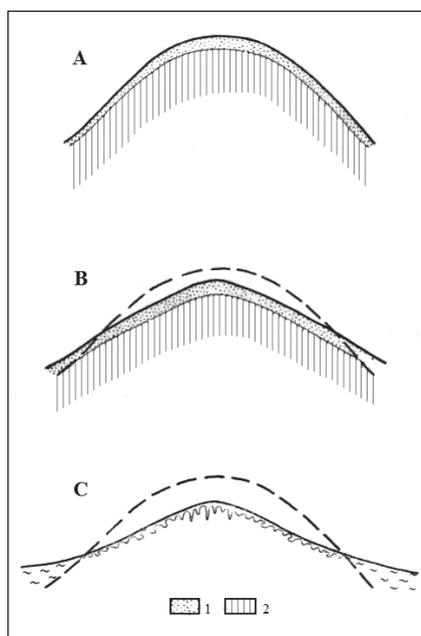
The last time the area surrounding Łódź was covered by ice-sheet was during the Warta Stadial of the Odranian Glaciation (170 000–140 000 years BP), whereas during the most recent Vistulian Glaciation, the area remained in the periglacial zone. Periglacial environment, with its specific geomorphological processes, developed in front of the foot of the Scandinavian ice-sheet. In the Holocene (the last 10 000 years), the area has remained in the temperate climate zone, thus, it was important to define the role of glacial, periglacial and fluvial processes in the formation of the relief of the area surrounding Łódź. Theories and hypotheses regarding the origin of the relief of Central Poland changed several times. In the 1950s and 1960s, the theory of periglacial character of the relief was predominant, while in the 1970s, the theory of glacial origin gained dominance only to be substituted by a thesis of a polygenesis of the relief. This work presents the evolution of the view regarding the origin of the relief of Central Poland with consideration for research methods.

## 1.2. The periglacial concept

The first intensive field research conducted by the Łódź centre was related to geological and geomorphological charting. In 1948–1950, Łódź geographers developed a *Łódź. Przeglądowa mapa geologiczna Polski w skali 1:300 000* (Łódź. An overview geological map of Poland, scale 1:300 000) (Dylik and Jurkiewiczowa 1950). It was a group work managed by Professor Jan Dylik. In 1950–1955, field research was conducted for a geomorphological map which has never been published. When a legend for the geological map was being developed, it became evident that it was difficult to establish a uniform legend for the areas of Northern and Central Poland (Dylikowa 1999).

The relief of the area of Northern Poland once covered by Vistulian Glaciation was different from the relief of Central Poland formed during an older Warta Stadial of the Odranian Glaciation. In the north, the relief is clear and vivid. There is a predominance of rolling moraine uplands with the not uncommon series of terminal

moraines. Other typical elements include various subglacial tunnel valleys, ice-margin valleys and sandurs (Galon 1972). In Central Poland, also around Łódź, relative elevations are considerably lower, raised forms are extensive and rounded, and there are many dips and dry valleys. In 1949, researchers found permafrost structures while charting the area. The difference of the relief of the younger and older glaciation gave rise to the hypothesis of the periglacial character of the relief of Central Poland, i.e. a huge denudation transformation of the glacial relief in the conditions of cold periglacial climate (Figure 1.1). It was formulated in the 1950s by J. Dylik (1952, 1953, 1956).

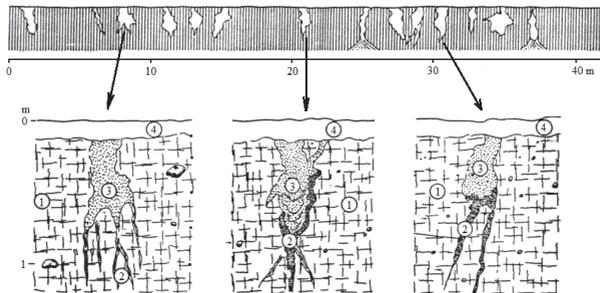


**Figure 1.1.** The huge denudation transformation of glacial relief in the conditions of cold periglacial climate in Central Poland

1 – active layer, 2 – permafrost

Source: J. Dylik (1953)

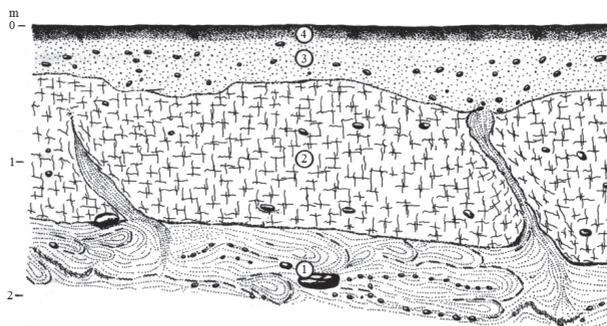
It was assumed that the initial glacial relief around Łódź was similar to a young-glacial (Vistulian) relief as seen today in Northern Poland (Balińska-Wuttke 1960, Różycki 1967). As the continental glacier receded, it revealed series of terminal moraines, whereas in periglacial conditions of the Vistulian, the relief was destroyed and tempered by intensive denudation of uplands and filling of depressions (Dylik 1953, 1960, 1963, 1969). Those processes lead to the formation of monadnocks and denudation planations which is why there are no obvious glacial accumulation forms. However, there would develop basin-like valleys, so typical for Central Poland, which were formed by linear erosion and flushing (Klatkova 1965). Pleistocene sediments have often been found to include structures indicative of long-term permafrost. The most important include uncovered gussets with primary sand or ice filling, pingo remnants, rock layer or involutive structures. Uncovered gussets are an emphatic evidence of the existence of long-term permafrost in the Vistulian. They occur in both fluvio-glacial sediments in kames and in Vistulian fluvial sediments (Klatkova 1965, 1996, Goździk 1973, Krzemiński 1965, 1974, Manikowska 1985, Turkowska 1988, Kobojeck 1990). Gusset remnants are best developed in loess, loose sands and clay (Figures 1.2, 1.3).



**Figure 1.2.** Fissures of thermal contraction

1 – till, 2- fine-grained sand, 3 – medium-grained sand, 4 – recent soil

Source: H. Klatkova (1993)



**Figure 1.3.** Periglacial slope deposits and thermal contraction cracks with the primary mineral infilling

- 1 – various-grained sands deformed by frost action and slope process operation,
- 2 – till slope deposits, 3 – various-grained sands with gravel,
- 4 – humus horizon of the modern soil

Source: S. Kobojeck (1990)

Polish studies in remnant periglacial forms and structures were the first of this kind in the world, particularly in relation to the role of periglacial environment in the formation of the relief of lowland areas. Considering the type of geomorphological notation and the age of forms and structures, Poland has been divided into three zones distributed along natural belts:

- belt of mountains and partly of highlands in the South where periglacial phenomena developed in outcrops of solid rock. The Wrocław centre was a leader of that research, including Professor Alfred Jahn (1951, 1956, 1970);
- belt of mid-Polish lowlands which overlaps the so-called old-glacial zone. The development of periglacial relief occurred during almost the entire most recent glaciation (ca. 100 000 years) and relief-formation processes occurred within loose rocks. The Łódź centre was a leader of the research;
- belt of lake districts and lowlands of Northern Poland which were under the influence of the most recent glaciation. Young glacial

relief was transformed and the period of development of the periglacial relief did not exceed 10 000 years (Rotnicki 1964, Kozarski 1971, 1986).

The development of the concept of the periglacial character of the relief of Central Poland, starting with the first works by J. Dylik, was exceptional. Many geomorphologists studied periglacial forms and structures throughout Poland but it was the Łódź school of geomorphology that was the most dominant (Mojski 2006). The reconstruction of periglacial conditions in Europe, Asia and North America based on the analysis of periglacial forms, sediments and structures was stimulated and targeted by the Periglacial Geomorphology Commission which was established in 1952 (H. Poser, J. Dylik). Łódź was also a place where the world-renowned *Periglacial Bulletin* was started. It was issued between 1954 and 2001. It included articles by not only Polish authors, but also all the well-known scientists of that time who studied periglacial processes. In 1956–1975, the Bulletin was an official body of the Periglacial Morphogenesis Commission of the International Geographical Union. J. Dylik was the chairman of the Periglacial Research Commission at the IGU between 1956 and 1972. It was a period of intensive contacts between Polish and international scholars and Łódź was where various symposia were held. Many monographies devoted to processes active in periglacial morphogenesis conditions in Central Poland (freeze, slope, aeolian, river or soil processes) and their results in the form of periglacial structures, sediments and relief forms were created at that time (Dylikowa 1958, 1967, Klatka 1962, Olchowik-Kolasińska 1962, Klatkova 1965, Manikowska 1966, Jewtuchowicz 1970, Goździk 1973, 1991, Jersak 1973, Kuydowicz 1975, Wieczorkowska 1975, Krajewski 1977). The development of periglacial research promoted the explanation of foreign terms which were defined in the Bulletin (Dylikowa and Olchowik-Kolasińska 1954, Dylikowa and Goździk 1995).

Nearly 20 years later, as new information was gathered, doubts arose regarding the dominance of the morphogenetic role of the

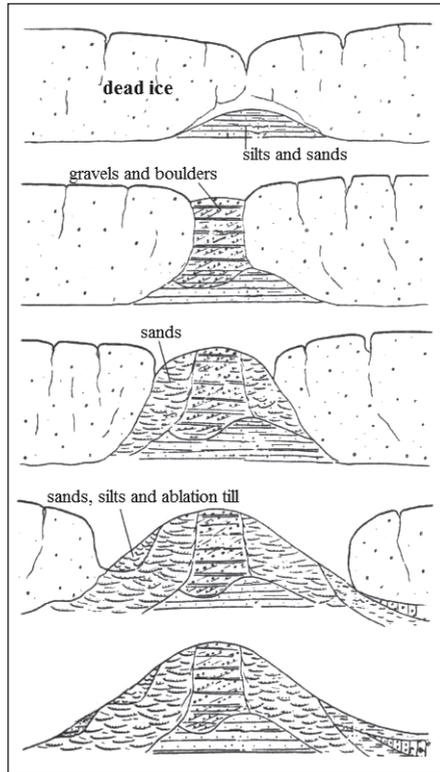
periglacial environment. Nonetheless, the indicators used for tracing the evolution of long-term Pleistocene permafrost developed by the Łódź centre are still valid and useful.

### **1.3. The role of glacial and fluvio-glacial processes in relief development**

Since the mid-1960s, glacial geomorphology has become an important research focus of Łódź geomorphologists. Detailed field research indicated a greater role of glacial processes than it was initially assumed. Analyses of forms and sediments were conducted over large areas of Central Poland. The researchers used numerous and often expansive outcrops (excavations) created for mining sand, gravel and clay. Additionally, since the 1980s, expansive walls of lignite open-pit mines in Bełchatów and Adamów and outcrops in the Jeziorsko reservoir cliffs have provided material for interpretation of glacial and fluvio-glacial sediments. Research methodology was also being developed, e.g. researchers conducted analyses of structural and textural features, lithofacies analyses of mineral sediments and palinologic analyses for organic sediments.

The research indicated that the main outline of the relief of the Łódź area is related to processes which occurred during the Warta Stadial of the Odranian Glaciation (Klajnert 1966, 1978, 1984, 2002, Jewtuchowicz 1967, Klatkova 1972, 1999, Krzemiński 1974, 1989, 1997, Wieczorkowska 1975, Wasiak 1979, Chrzanowski 1980, Rdzany 1992, 1997, 2009, Załoba 1996, Koboжек 1996, 2000). However, the glacial relief of Central Poland formed by Warta ice-sheet was different from the young-glacial relief of Northern Poland – gentler, calmer, without large terminal moraines (Krzemiński 1974). It is dominated by forms related to areal recess of glacier: hills and kame ridges, ground moraine plains, kettles and dry valleys. Z. Klajnert (1966, 1978) identified three specific zones of kame structure. The internal zone of kames is composed of fluvio-glacial sediments accumulated in opened ice cracks, followed by ice-contact sediments

and ablation sediments. By analysing the distribution of sediments in kames one can trace consecutive stages of the recess of dead ice surrounding kames (Figure 1.4). New authors continued detailed sedimentology research describing specific environments of sediment deposition (e.g. Jaksza 2006, Rdzany 2009).

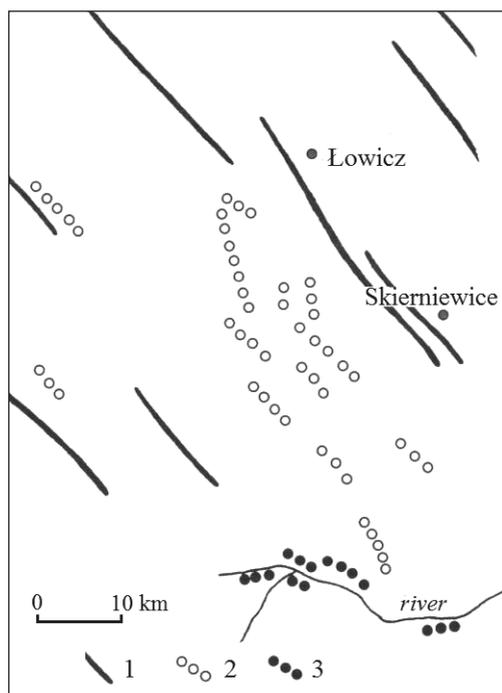


**Figure 1.4.** Main stages of development of the kame in Prażmów

Source: T. Krzemiński (1974)

Some researchers have indicated the influence of older geological structures (faults and salt structures) on the course of glacial processes in the Pleistocene (Klatkova 1972, Klajnert 1978, Rdzany 1997,

Forysiak 1996, Koboжек 2000). They highlighted the influence of late-Quaternary neotectonic movements on the directions of ice sheet cracking and, as a result, the characteristic extension of kame ridge axes from the south-east towards the north-west (Figure 1.5). This morphological direction of kames, related to the direction of structural axes of the Pomerania-Kuyavian Ridge, was called “Mesozoic” as a distinction from other possible local directions (Klajnert 1972).

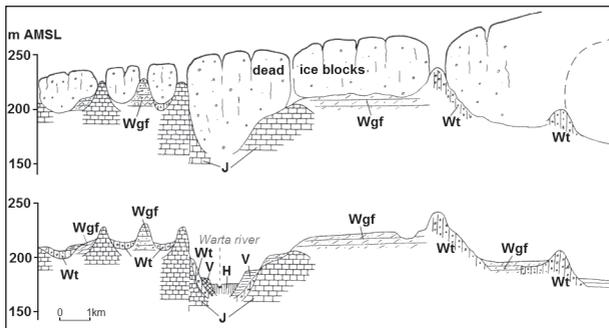


**Figure 1.5.** Kames against the background of geological structure on the Wysoczyzna Rawska (Rawa Interfluvium) and Równina Łowicko-Błońska (Łowicz-Błonie Plain)

1 - main tectonic directions of the Mesozoic bedrock (faults, anticline and syncline axes), 2 - morphological axes of kames on the interfluvium, 3 - morphological axes of kames in the valley

Source: Z. Klajnert and E. Koboжек (1992)

Extensive under-ice dips, often of tectonic or structural character, were particularly important for the glacier decline (Figure 1.6). During areal deglaciation, melt waters flowed off along the general decline of the immediate glacier basis. Valley-type under-ice dips served the main role in the runoff of ablation water (Klajnert and Rdzany 1989, Klajnert and Wasiak 1989, Rdzany 1997, Kobojeck 2000, Klajnert and Kobojeck 2003). The ice-sheet was thicker in under-ice dips and thinner in nearby elevations (Figure 1.7). A general thinning of the ice sheet caused by melting resulted in the creation and deepening of cracks and all types of free inter-ice spaces. Locations of abrupt collapses of under-ice surface decline offered good conditions for depositing fluvioglacial material and creating characteristic forms. Researchers identified a significant relationship between the direction of ablation water runoff and the contemporary distribution of river networks.



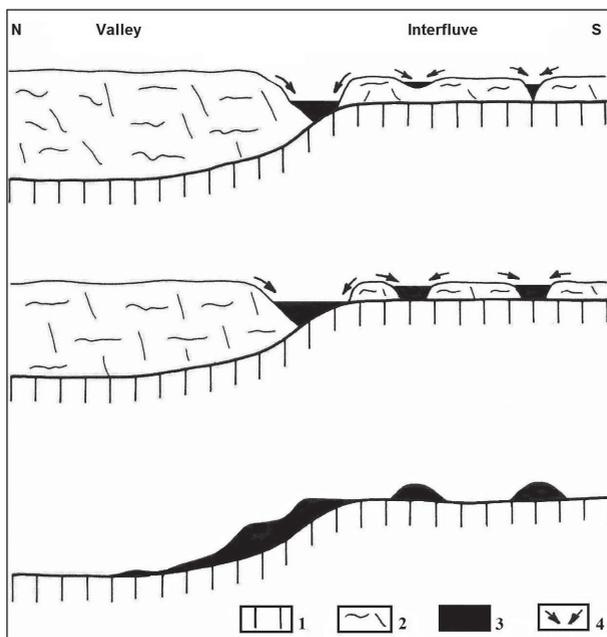
**Figure 1.6.** Glacial morphogenesis of northern part of the Wyżyna Wieluńska (Wieluń Upland)

J – limestones Upper Jurassic, Wt – till of the Warta Stage,  
 Wgf – glacifluvial sediments of the Warta Stage,  
 V – fluvioperiglacial sediments of Vistulian, H – fluvial deposits of Holocene

Source: T. Krzemiński (1974)

Glacial relief in plateaux was transformed slightly in the conditions of periglacial and temperate climate, while Plenivistulian

upper fluvial terraces and Holocene fluvial terraces formed in river valleys (Turkowska 1988, Wiczorkowska 1989, Koboжек 2000, Petera 2002, Forysiak 2005).



**Figure 1.7.** Phases of relief development at the northern slopes of the Wysoczyzna Rawska (Rawa Interfluvium) at the end of Warta Stage

1 - ice-sheet base (substratum), 2 - glacier ice, 3 - glacial deposits, 4 - directions of water flow

Source: Z. Klajnert and E. Koboжек (2003)

Research was also conducted in stratigraphy and the coverage of the Warta Stadial while a detailed study is presented in an article by D. Dzieduszyńska, J. Petera-Zganiacz, M. Roman and L. Wachcicka-Kotkowska in this volume. The role of the Wartanian ice-sheet was discussed, e.g. during the international conference of 1994:

“The Cold Warta Stage: lithology, paleogeography, stratigraphy”, 11<sup>th</sup>–15<sup>th</sup> October, Łódź. It was organised by H. Klatkowa as part of the operations of the European Quaternary Stratigraphy Sub-commission of INQUA (International Quaternary Association).

#### 1.4. Polygenetic relief

Further research conducted using modern methods indicated several processes responsible for the final look of the land relief forms. It was decided that some of them were polygenetic in nature. Polygenetic relief (from Greek *polýs* – numerous and *génos* – origin) was understood as a complex development of land relief forms influenced by various factors. It is impossible to indicate a single process responsible for the current land relief. Researchers aimed at indicating the relationship between glacial and periglacial processes in the final formation of the relief of Central Poland (Wieczorkowska 1989, Rdzany 1997, Turkowska 1996, Kobojeck 2006, Wachecka-Kotkowska et al. 2012). Forms with complex origin include, e.g. river valleys, dry valleys and the so-called alluvial fans zone.

Valley forms formed in the final stage of the Warta Stadial and the highest terrace level originated in that period. They were formed by fluvio-glacial processes (Klatkowa 1972, Krzemiński 1974, Turkowska 1988, Kobojeck and Przybył 1993, Kobojeck 2000). Further development of river valleys occurred in periglacial conditions of the Vistulian and in temperate climate of the Holocene.

Dry valleys, which differ in length, width, depth and slope inclination, are a rather common element of the relief in the analysed area. Apart from short and deep forms, there are also long, wide and basin-like formations. One feature common to all of them is that they lack a permanent stream. Dry valleys often accompany glacial relief and they were formed as a result of melting of bodies of dead-ice (Klatkowa 1972, Krzemiński 1974, Klajnert 1978, Rdzany 1997, Kobojeck 2000). Rivers in the initial cataglacial stage of the Warta Stadial fed mostly by glacier waters formed shallow and wide valley

depressions. Their functioning declined as the supply of surface water from melting glacier diminished. The valleys start high in kame slopes and continue in extensive kettle depressions.

The bases of many dry valleys include kettles (small lakes) of low diameter and fairly deep, under 20 m deep, cut in glacial and fluvio-glacial sediments of Warta Stadial. Those reservoirs are filled with organic material, such as peat, gyttja and lake limestone dated at the Eemian (Klatkova 1972, 1989, Manikowska 1997). Dry valleys were the perfect location for denudation processes in periglacial conditions. Forms with diverse relief were subject to more remodelling than those with less inclined slopes.

Apart from dry valleys, which started to form in the final period of the Warta Stadial, the relief also includes younger erosion-denudation forms (Dylik 1966, Klatkova 1965). They formed in periglacial climate conditions in the Vistulian particularly in the slopes of river valleys with rather high elevations and expanded to the surfaces of upper fluvial terrace. Their development was mostly related to flushing.

Dry valleys the bottoms of which are located above the range of underground water level fluctuations were and still are formed by the flow of surface waters. In the Holocene, plant life considerably suppressed or completely even prevented their development. The removal of plant life by humans resulted in increased erosion which is why erosion recesses (gullies) developed in the bottoms of some older forms.

Studies of dry valleys located in different morphological circumstances indicate their complex origin. Neighbouring forms formed in different periods with a dominance of slightly different processes.

Poligenetic forms also include the so-called alluvial fans zone. It is an extensive, latitudinal area with a slight inclination from the south towards the north and the north-west. It is composed mainly of sand and some gravel, with an infrequent addition of mudstone. The area is cut by several shallow valleys or covered by dunes. Detailed field research of the area and laboratory analyses of collected sediment samples as well as measurements of the strikes and dips of

laminae enabled researchers to identify three types of formations. Horsts formed during Wartanian ice-sheet recession as a result of accumulation of fluvio-glacial sediments (Brzeziński 1991). Vistulian slope deposits occur in very narrow zones of fairly inclined surfaces, e.g. in river valley edges. Alluvian fans composed of sand accumulated in the environment of periodically flowing water in the Vistulian, i.e. fluvio-periglacial, formed at the mouths of dry valleys and denudation valleys. The existence of permafrost facilitated the processes of flushing, downhill creep and solifluction. All those deposits are covered by aeolian sand of variable thickness (Goździk 1995). Dunes formed in many locations. Thus, it has been decided that the origin of this area is polygenetic (Klajnert and Kobojek 2003, Kobojek 2012).

## 1.5. Conclusions

Hypotheses, concepts, problems and methodology are vital for academic research. First of all, it is necessary to formulate a concept, ideally one which is coherent and based on simple and physically feasible premise. Then comes the time for long and tiresome verification of details and amalgamation of the new theory. Usually researchers first notice those facts which substantiate the new concept, but, in time, they identify more and more exceptions and local irregularities, which is why the concept starts losing its simplicity and the results of further research increasingly indicate a possibility of other solutions. A new concept arises and thus science develops. The appearance of new hypotheses requires scientists to maintain high level of research. Already in 1934, K.R. Popper wrote that whenever we propose a solution to a problem, we ought to try as hard as we can to overthrow our solution, rather than defend it (Popper 2002).

The research conducted by Łódź geographers and geomorphologists since 1945 has offered insight into the relief and geological composition of Central Poland. The development of glacial relief and

the scale of transformations in periglacial conditions have been documented thoroughly. Long discussions between the proponents of periglacial and glacial concepts have led to a proper evaluation of the importance of individual processes of relief origin, at least to the level which is accepted today. Nowadays, Łódź geomorphologists continue extensive research of the processes which occurred in the Vistulian in periglacial and glacial environments a theme which is covered in the study herein by D. Dzieduszyńska et al. (2014). New directions of research include the influence of human activity on geomorphological processes and transformation of relief (Twardy et al. 2014).

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