

## PRELIMINARY RESULTS OF GEODETIC MEASUREMENTS IN THE INOWROCLAW SALT DOME AREA, CENTRAL POLAND

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**Abstract:** The results of geodetic measurements conducted in the Inowrocław salt dome area are presented in this paper. The main aim of these studies was to determine changes in the rock mass exerted by geological processes. These processes have led to the changes in the salt dome geometry and physical properties of surrounding rocks. Degradation of the salt–gypsum cap of the dome strongly depends on the hydrogeological conditions and, particularly, on tectonic structure which has had a bearing on the uplift of the ground surface. The principal goal of the paper is to present the results of geodetic levelling surveys in the Inowrocław area wherein the mining activity was terminated in 1991. These results point to a progressive salt uplift in some areas, showing a constant rate throughout the study period.

**Key words:** geodynamics, salt geology, levelling, subsidence, mining, Inowrocław salt dome, central Poland.

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### INTRODUCTION

The uplift of the Inowrocław salt dome has been discussed in view of the results of geomorphological (Niewiarowski, 1983), geodetic (Wyrzykowski, 1975), and structural analyses (Tarka, 1992).

Although the existing literature on vertical crustal movements in the Kujawy area is abundant, the suggestions of salt structure uplift have rarely been supported by adequate data. Therefore, papers by Niewiarowski (1983) and Tarka (1992) are of special importance. The first paper, based on geomorphological studies, documents postglacial uplift of salt domes in Inowrocław and Góra, proceeding at a rate of 1 mm/year. The second paper discusses at large gravitational and tectonic theories of salt domes origin, concentrating on the causes of uplift observed at Inowrocław and emphasizing their tectonic control.

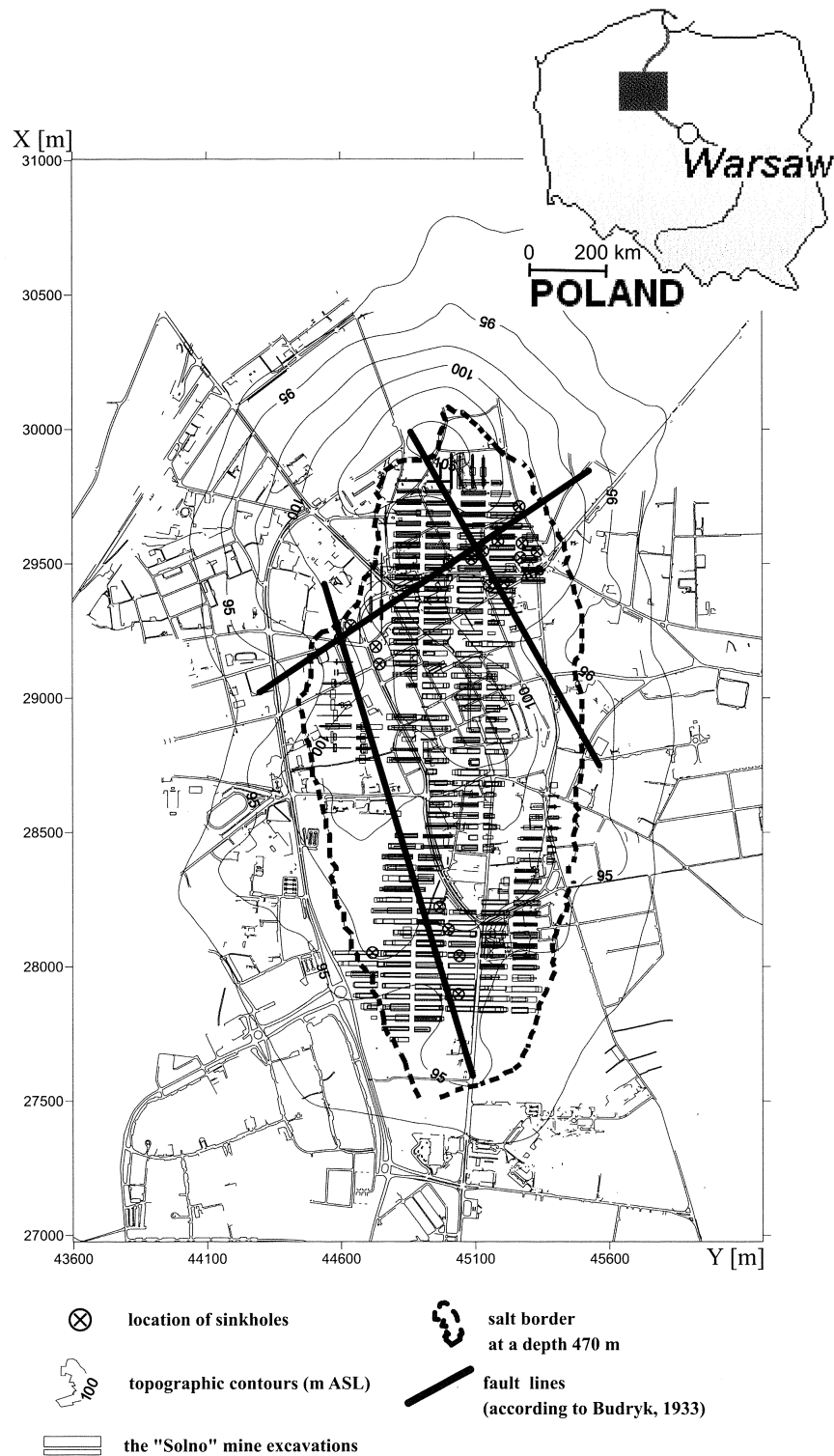
Due to the salt mining exploitation by the Solno mine and related deformations, it was impossible to detect geodetically small changes resulting from uplift of the salt structure. The closure of mining activity in Inowrocław and liquidation of excavations by flooding in 1991 stopped the subsidence which used to be registered for decades. The recently observed uplift detected by geodetic methods is not related to the mining activity.

### GEOLOGICAL SETTING OF THE INOWROCLAW DOME

Geological setting of the Inowrocław salt dome has been dealt with by numerous authors, usually in the aspect of subsidence process affecting the cap rocks (Poborska-Młynarska, 1984) or its effect on discontinuous deformations (Budryk, 1933; Poborski, 1957). According to some geologists, these are the processes originally related with the uplift of the salt structure. The result of diapirism are both the salt dome and a small hill, being a surface expression of halokinetic squeezing of salt masses (Fig. 1). The internal structure of the salt dome was explored quite well owing to mining activity (Bujakowski 1986, Ney & Ślizowski 1991, Tarka 1992).

The salt dome geometry in plan view resembles an ellipse, 3 km by 1 km across. It is located as a salt dome at Góra on a morainic plateau that is free of convex marginal forms. Both the eastern and western sides of the salt structure are steep or even upright (Fig. 2). The surface of the salt roof is situated 120–190 m below the ground surface and it is covered by cap rocks, 50–180 m thick (Fig. 2).

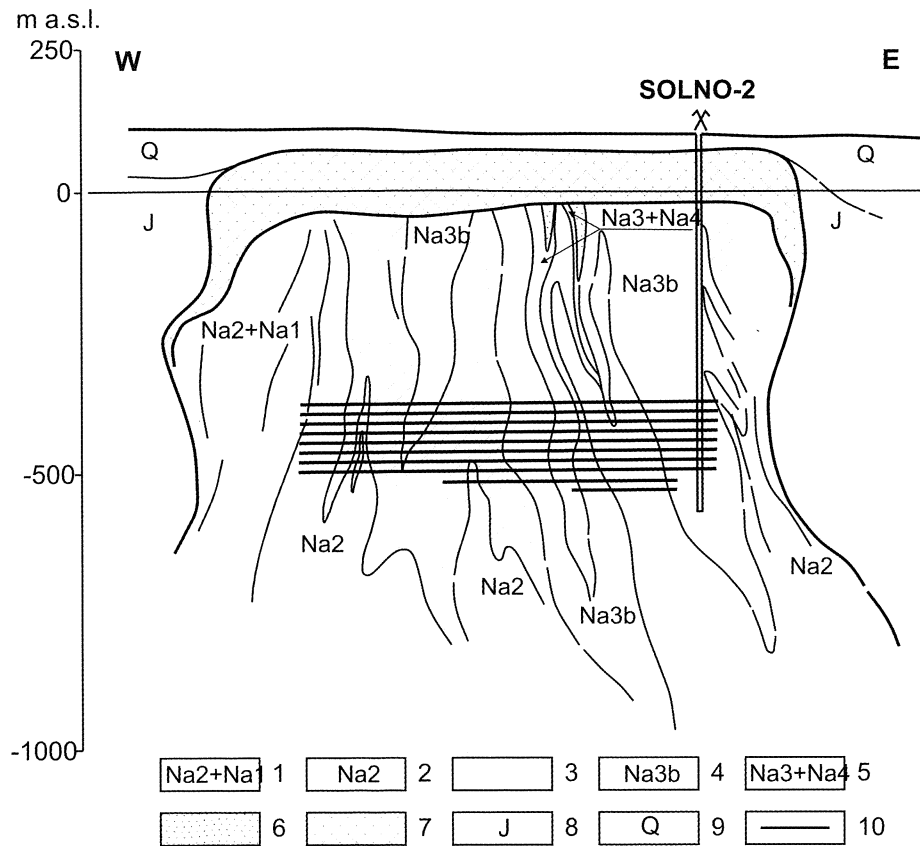
In the area of the dome, the Quaternary formation is reduced even to a few metres, but the dome's surroundings are built up of a displaced Jurassic complex of limestones. To-



**Fig. 1.** Location map of the Inowrocław salt dome area (coordinates are in a local geodetic system)

pographically, the dome is diversified and its irregularity on the top surface is caused by karst processes. According to Niewiarowski (1983), it complicates the determination of the scale of uplift, although this irregularity in the salt structure's top surface, its features, the thickness of cap rocks, and their extent provide information on hydrogeological conditions of the dome. In case of the Inowrocław dome, these conditions are controlled by fault zones, already men-

tioned by Budryk (1933) and Poborski (1957). Budryk (1933), by using old observations conducted during shallow mining, described the system of faults determining the underground water circulation, and the structure of sinkholes which have been formed without any relation to mining activity. These faults intersect one another in the northern part of the dome (Fig. 1).



**Fig. 2.** Tectonics of the Inowrocław salt dome (after Poborski, 1957; and Bujakowski, 1986). 1 – The Older Rock Salt with a possible occurrence of the Oldest Rock Salt, 2 – the Older Rock Salt, 3 – the Younger Rock Salt (lower part), 4 – the Younger Rock Salt (upper part), 5 – the Younger and the Youngest Rock Salt, 6 – the Youngest Rock Salt, 7 – cap rocks and anhydrite, 8 – Jurassic, 9 – Quaternary, 10 – The Solno mine's levels

As a result of diapiric processes, the salt body reached a level at which it was a subject to underground solution (subrosion). In that case, areas affected by intensive subrosion (and resulting from that process cavities) demonstrate the salt uplift activity. The calculated rate of dissolution processes of rock salt in ground water is 1 mm/yr for the Inowrocław dome. It means that 1 mm thick layer of salt (the top surface of rock salt) is dissolved and removed away. The subsidence resulting from subrosion is compensated by uplift (Poborska-Młynarska, 1986)

The mining activity in Inowrocław started in the XIXth century. The first shaft was sunk between 1873–1878, and later two more shafts were sunk. Salt was extracted in two underground mines and by solution mining (pumping mostly a natural brine). Such a mining activity was concentrated in the southern part of the deposit. The mines were catastrophically flooded in 1907, therefore, salt extraction was continued only by solution mining (water was pumped into the underground rock salt deposits from above the ground to produce fully saturated brine, which was then pumped back to the surface), and brine evaporation.

The harmful effect of that shallow salt mining was the surface subsidence and sinkholes. So, between 1924–1933, the Solno mine was built (as “a safe mine”) with the first level below the older mines. Considering rock mass stabilization, a new system of mining was involved – the rock salt was mined by room and pillar system at 10 levels and the

extraction varied in depth from 479 m to 637 m. The mine was closed down in 1986, and all excavations were definitely flooded by brine in 1991.

## PRELIMINARY GEODETIC RESULTS

The levelling measurements carried out by the AGH-UST team in 2002 were connected with the determination of the heights of network benchmarks established within the framework of a Polish Committee for Scientific Research (KBN) project. The main aim of the project is to determine changes occurring in salt rock mass, as a consequence of mining and natural subrosion. Additionally, the still existing old mine's benchmarks were measured during the levelling survey. The precise levelling method was used, applying the same technology as during previous survey sessions, giving satisfying results within the required accuracy: the mean error of height determinations after adjustment amounts to 2.2 mm/km. The observations of height changes referring to most of the points have been conducted for 40 years.

Over the years, as a result of mining exploitation, the changes were negative. However, since 1991, in the connection to the Solno mine close-down (with filling up all the excavations) the rate of movement of some points slowed down or even stopped, and in the following years positive height changes were registered, showing uplift at selected

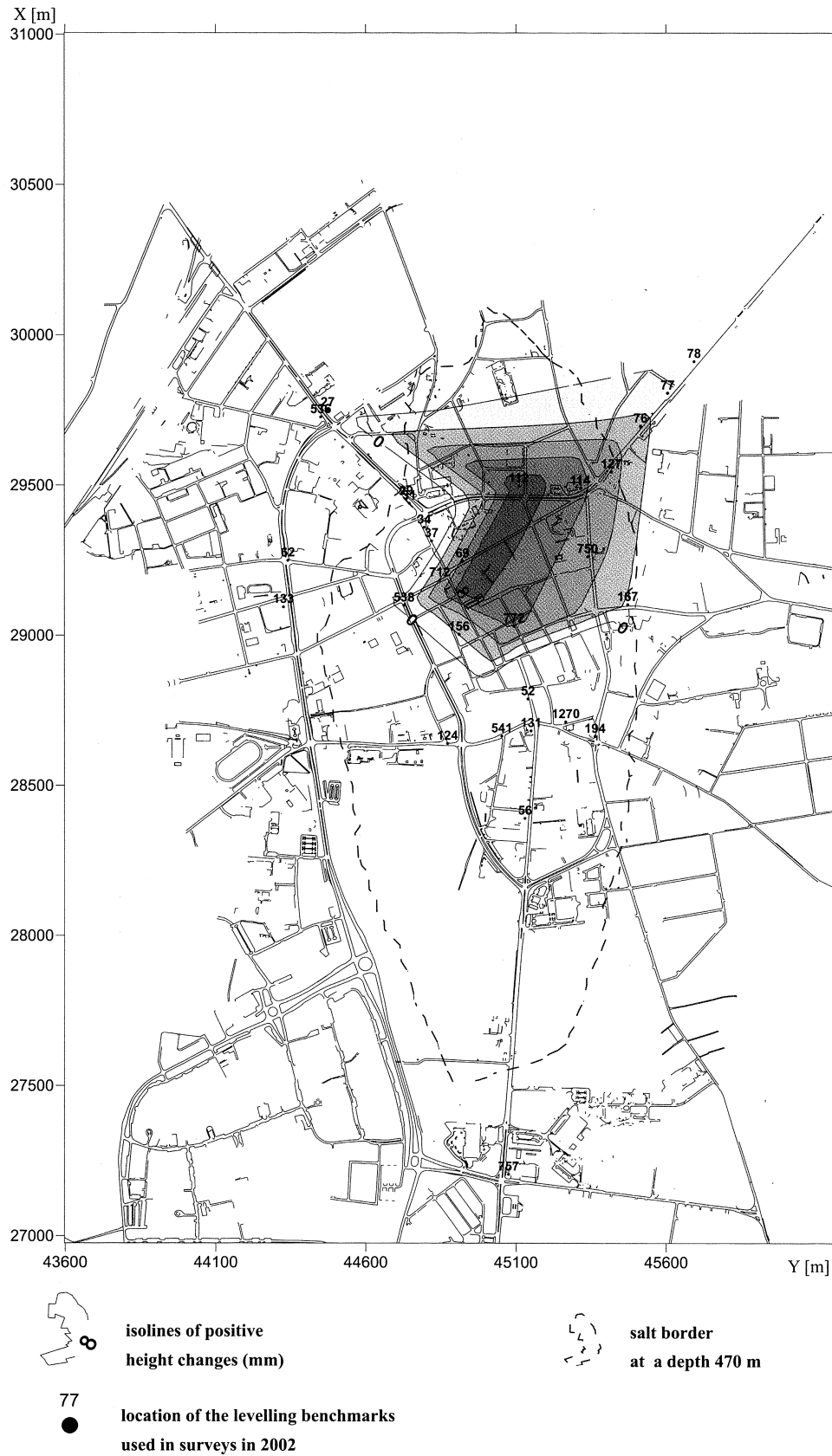


Fig. 3. Provisional border of the salt dome and the area of detected positive height changes

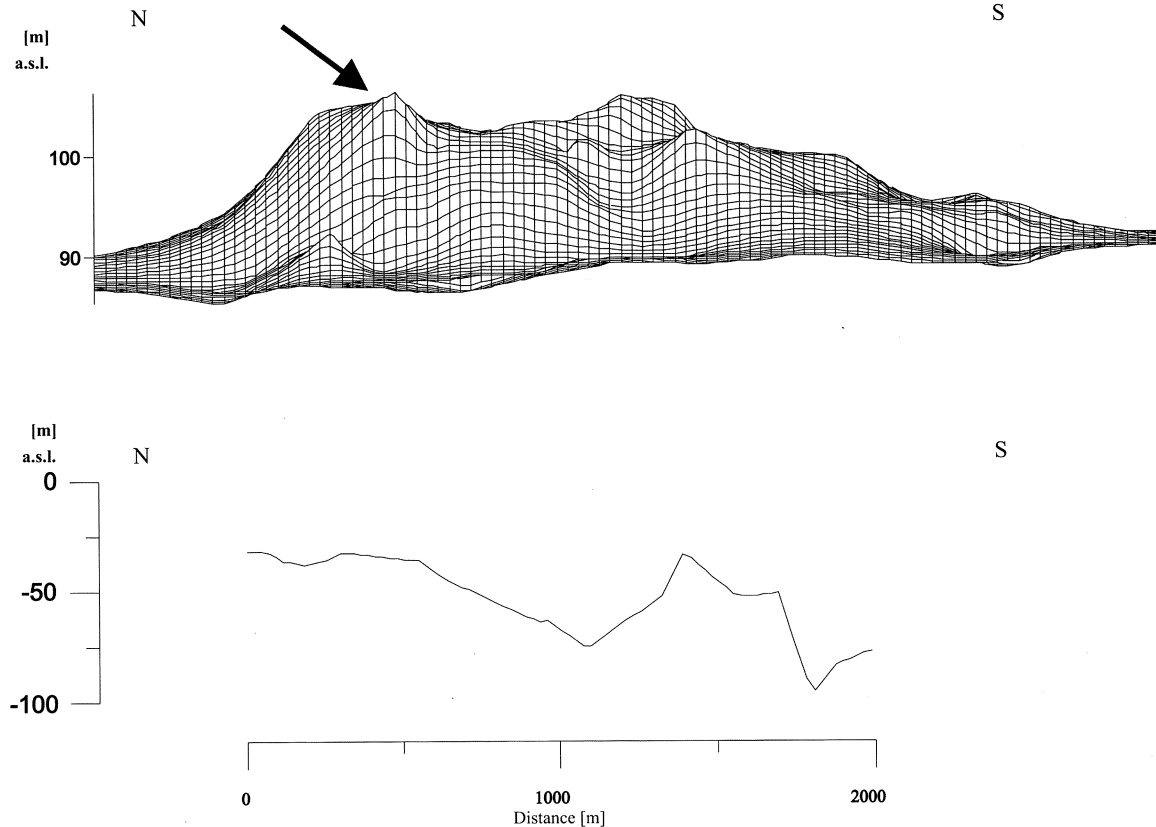


Fig. 4. The area of positive height changes (arrow) shown in a perspective view of the topography of the Inowrocław area and N-S profile through the salt structure (in the bottom part of the picture)

points. That happened in the northern part of the salt dome, and levelling results of the years: 1992, 1995, and 2002 confirmed the occurrence of uplift tendency. In the southern part of the deposit, the subsidence is, however, still observed. This can be caused by the influence of old shallow mining carried out at the beginning of the 20th century, due to mine drainage.

Precise levelling observations, conducted for decades every 1–2 years, have shown a good accuracy. In 2002, after 7 years break (currently after the mine closed down the measurements are not carried out), the levelling observations were conducted by AGH-UST research team measuring selected (about 30) benchmarks. One third of them demonstrated positive height changes in the relation to both 1992 and 1995. Even though the changes were slight (the maximum value of uplift was 10 mm in the period of 10 years), the estimated trend of uplift and its spatial distribution eliminates its randomness. The uplifted area extends behind the horizontal range of the Solno mine excavations. Fig. 3 demonstrates the location of the detected positive height changes.

## DISCUSSION

Due to the limited levelling range, i.e. the relatively small number of points, the conclusions concern rather the scale and location of the observed uplift than its spatial extent. Moreover, an additional factor interfering in the quan-

titative interpretation of the process is the still existing effect of post-mining excavations, which is testified to by subsidence observed in the southern part of the former mining area. The recorded values of uplift at individual points are controlled by the influence of old mining. Nevertheless, the obtained results demonstrate certain regularities related to the geological structure of the salt dome. The uplift occurs in the northern part of the dome, where the salt roof is situated close to the ground surface. Moreover, sinkholes formed by subsrosion processes in that area (many of them occurred before the beginning of mining) provide good hydrogeological conditions for degradation processes of the salt dome.

According to Budryk (1933), the local conditions are strictly related to fault zones wherein gypsum solution process or destruction of clay rocks is particularly intensive. The maxima of detected uplift are situated in the area of cross-cutting of fault zones, mentioned by Budryk (1933) and currently documented by geophysical methods.

The salt dome morphology demonstrates a similarity to the ground surface topography, which is consequently related to the registered uplifts; the area of the maximal uplift is situated on the highest part of the hill, wherein the elevation of the salt structure is the highest (Fig. 4). Moreover, the area is historically known as a place affected by sinkhole deformations, resulting from intensive karst process (Budryk, 1933; Poborska-Młynarska, 1984). Maximal values of detected uplifts can be higher than the measured ones, because the survey was carried out only at selected points, and

the observed values include a component related to the decreasing post-mining subsidence. However, the obtained maximal value of uplift of +10 mm in the period of 10 years demonstrates a constant rate. It is the value which was surprisingly compliant to the one determined based on geomorphologic studies by Niewiarowski (1983).

## CONCLUSIONS

The above discussed studies of uplift of the salt structure are important in terms of the advance in scientific knowledge, but they have also practical aspects. The observed height changes and sinkholes are direct results of these movements, which – according to the obtained results – depend on the dome's tectonics. The interaction of the above mentioned processes and adjusting factors can be determined with the application of both geological and geodetic methods (Szczerbowski, 2002).

The identification of geological processes influencing city buildings presents a significant factor for spatial development planning. This community aspect of the project requires an application with the reference to engineering practice (determination of building safety) and knowledge of geological processes influencing the salt dome at Inowrocław. Consequently, the obtained results will contribute to the knowledge on the uplift process of the Inowrocław dome.

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## Streszczenie

### WSTĘPNE WYNIKI BADAŃ GEODEZYJNYCH W REJONIE KOPUŁY SOLNEJ INOWROCŁAWIA W PÓŁNOCNO-ZACHODNIEJ POLSCE

Zbigniew Szczerbowski

W pracy przedstawiono geodezyjne wyniki rozpoczętych w rejonie Inowrocławia badań. Ich celem jest określenie zmian zachodzących w górotworze w wyniku działania procesów geologicznych. Generalnie, skutkiem działania tych procesów są zmiany zachodzące w wysadzie solnym w zakresie jego geometrii jak i jego własności fizycznych (zmiana parametrów fizycznych skał na skutek podziemnej erozji złoże). Procesy degradacji czapy iłowo-gipsowej wysadu są silnie zależne od warunków hydrogeologicznymi, a w szczególności od budowy tektonicznej, która z kolei jak się wydaje ma wpływ na obserwowany na powierzchni ruch wysadu. Omawiane wyniki niwelacji wskazują na postępujący proces dźwigania struktury solnej (w niektórych rejonach), którego wykazuje stałe tempo w okresie badań.