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## ON THE ORIENTATION OF CZECH CITIES FOUNDED DURING THE 13<sup>TH</sup> CENTURY

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### ABSTRACT

During the 13th century the Czech state became a major power, significantly influencing the political situation in Central Europe. Alongside with the increasing positions of power of the Czech state, important changes also occurred in the interior of the country. Remarkable economic development led to a process of urbanization throughout the country's territory. Concurrently in the wider European region similar political, social and economic changes favored analogous developments, including a new intellectual movement reviving the ancient Greek natural philosophy, including astronomy. It is certain that this fact did not leave unaffected the architectural thought and creativity of the era. The present paper studies the orientation of fifteen of these new Czech towns, developed in the late 13th century, for a possible astronomical connection.

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**KEYWORDS:** Orientation, Czech medieval cities, Urbanism, Ottokars

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## 1. INTRODUCTION

It was only in the 11th century that around Europe the gradual renewal of more advanced forms of economic life began. The momentum of the whole process was a marked rise in agricultural production, driven by increasing demographic pressure. Not only the volume of cultivated land had grown, but more advanced farming methods were taken up. More advanced breeding and milling techniques have helped to intensify field cultivation. The man began to dry swamps and wetlands, and cultivation expanded to more mountainous and less fertile places. Extensive work on the construction of settlements was driven mainly by household settlers, but later on both close and more distant areas in medieval Europe were also penetrated by foreign colonists (Žemlička, 1990). Thus, between 1000 and 1200 the population of Europe may have doubled, tripled or even quadrupled, while the city-dwelling portion of this population increased even more rapidly. Urbanization in turn, provided economic opportunity, allowed for the concentration of wealth and encouraged the growth of schools and intellectual culture (Lindberg, 1992). The 13th century was more auspicious than the 12th. Within a comparatively peaceful Christendom, individual nations began to take shape and to establish their national institutions. Gothic architecture flourished, while the great universities of Northern Europe were established (Kenny, 1998).

## 2. MEDIEVAL EUROPE: AMBIANCE AND CHANGES

In the turn of the second millennium the improvement around Europe was lasting and many-sided. 11th century began with monastic reform, then extended to the papacy and church government, while towards the end of the century it produced the first scholastic philosophers. 12th century was a transitional historical stage. The crusades gradually came to an inglorious end, the conflict of empire and papacy continued, rise of the Lombard cities occurred, while the growth of scholasticism continued. In the 13th century, the Pope triumphed over the Emperor, the Lombard cities acquired secure independence and scholasticism reached its highest point (Russell, 2004).

During the 11th and 12th centuries, the cathedral schools in many European cities became intellectual centers that attracted students and teaching masters. In these schools, future clergy learned Latin, the language of Church. They also learned enough arithmetic to perform calculations with Roman numerals and to cope with calendrical problems, both secular and religious. To some degree, they were taught the rudiments of the seven liberal arts

and they even studied classical Latin literature through which they were exposed to a broader cultural history. From the 10th to the 12th centuries some great teaching masters emerged, who attracted students from all over the Europe and trained other teaching masters (Grant, 1996).

Nothing is more striking in the history of the 12th century schools than the rapid increase in the numbers of students who flocked to them. Formal organization existed in embryonic condition here and there, but the rise of universities, recognized centers of learning with special rights to issue degrees, was an event of the late 12th and 13th centuries. Even then, learning was in some measure dependent on libraries, traditions and organization. The church had the basic framework of an organization in cathedral schools, governed under the bishop, by cathedral chancellors or “masters of the schools” of a diocese. The main repositories of ancient learning were the libraries of cathedrals and monasteries, especially in the centuries following the Carolingian renaissance (Brooke, 1969). As part of a program to strengthen church and state, Charlemagne undertook educational reforms, ordering the establishment of monastery and cathedral schools throughout the realm. This contributed to a wider dissemination of education than the Latin West had seen for several centuries and led to the aforementioned bloom of scholarly activity (Lindberg, 1992).

It is widely agreed that a close relationship exists between education and urbanization. The disappearance of the ancient school was associated with the decline of the ancient city and educational invigoration followed quickly upon the re-urbanization of Europe in the 11th and 12th centuries. Following the population shift to the cities in the 11th and 12th centuries, urban schools of various sorts, emerged from the shadow of the monastery schools and became major educational forces. The educational aims of the new urban schools were far broader than those of the monastery schools. Even the cathedral schools, which resembled the monastery schools in having exclusively religious aims, based their curriculum on a broader conception of a range of studies that would contribute to religious ends (Lindberg, 1992).

The product of these new arrangements was a rapid broadening of the curriculum, while the urban schools, like European society more generally, saw a marked “rationalistic” turn – that is an attempt to apply intellect and reason to many areas of human enterprise. Natural philosophy did not hold central stage in the 12th century schools, but it did benefit from the general intellectual ferment. A new conception of nature appeared during this period, as an autonomous rational entity, which proceeds without interference according to its own principles. There

was a growing awareness of natural order or natural law and a determination to see how far natural principles of causation would go in providing a satisfactory explanation of the world. That is why medical and astronomical treatises, which both rested on philosophical foundations, where the most commonly selected material to be translated in the 10th and 11th centuries. While early in the 12th century the emphasis seems to have been on astrological works, along with the mathematical treatises required for the successful practice of astronomy and astrology. The aim was clearly utility, broadly defined (Lindberg, 1992).

The new concern for nature and its operations generated an intense interest in the works of Greek antiquity, many of which were available only in the Arabic translation. Thus to the Greek legacy must be added the contributions of numerous Islamic authors, a group that includes not only Muslims but also Christians and Jews, who were bound together by their common use of the Arabic language. Treatises from Arabic and Greek were translated into Latin already in the middle of the 10th century in northern Spain at the monastery of Santa Maria de Ripoll at the foot of the Pyrenees. These works largely concerned with geometry and astronomical instruments. But the translating activity that revolutionized Western scientific thought and determined its course for centuries to come, occurred in the 12th century and, to a lesser extent, in the 13th. The great age of translation was preceded by the rollback of the Muslims in Spain and their defeat in Sicily during the 11th century. Reinvigorated Western Europe came into possession of significant centers of Arabic learning. Books in Arabic were readily at hand and intellectually starved Europeans were eager to make their contents available in Latin, the universal language of learning in Western Europe. Scholars came from all parts of Europe to join with native-born Spaniards, whether Christian, Jew, or Muslim, to engage in the grant enterprise of converting technical science and natural philosophy from the Arabic language into Latin (Grant, 1996).

### 2.1. *The establishment of new towns*

From the middle of the 12th century onward, hundreds of towns were founded under a variety of conditions. They were granted municipal charters by their territorial rulers and these charters regulated the communal life of the burghers as well as their relation to their rulers and to other political units. The urban charters developed in the course of a struggle with older and superior ecclesiastical or state powers (Braunfels, 1988). Their plans were irregular due to the nature of the sites on which they were built, often initially for defensive purposes. In

some other cases even though the city may have been started according to a regular plan, it may have been continued on quite irregular lines due to the accumulation of different trade unions around the central market area, which had its effects on the form of the medieval city. But that was by no means always the case; medieval drawings exist of regular geometric planning. These are plans for monasteries, such as the well known design drawing for the Abbey of St. Gall and according to the location, such monasteries provided the seeds from which many medieval cities grew (Broadbent, 1990).

Although they appear irregular and picturesque, the settlements of the later Middle ages are based on symbolic principles of organization. They resemble a living organism where the wall is the hard shell and the church the delicate core. In between are the dwellings, which represent an intermediate character. The city wall, however, was more than a symbol of the *civitas*, a domain reigned by law, order and security. In the *civitas* man was free. Although the conscious wish for order brought about a revival of Roman principles of organization in the medieval town, the quadripartite plan combined with the Christian concept of interiority. As a result, the urban environment is experienced as simultaneously structured and intimate. The basis of the quadripartite plan was the conception of the town as a representation of an ordered cosmos, where life could take place in an analogously ordered way. Indeed the whole medieval world was imagined as a quadripartite totality with Jerusalem and Rome forming a double center. The ancient symbolism of the cardinal points was thus revived (Norberg-Schulz, 1975).

### 3. 13<sup>TH</sup> CENTURY IN THE CZECH LANDS: CHANGES AND NEW TRENDS

This new wave of revolutionary changes that swept slowly all Europe, in the Czech lands it appeared belatedly. It was observed from 13th century to last the two subsequent centuries, until the Hussite wars.

It was during the reign of the king Ottokar I (1192–1230) when began not only the epoch of power boom of the Czech kingdom, but also the changes that during the 13th century saw the reconstruction of the early feudal principality in a strong monarchy with a developed economy, a rich social base and a rich cultural background. In the course of a century, the character of the Czech lands changed. The municipal towns and marketplaces intertwined the lowlands and expanded into the more remote parts, caused significant changes in the contact of the urban environment and the country. The completion of the re-establishment of the Czech lands was also attended by foreign influences, especially German

colonists. They brought the knowledge of the new organizational forms of towns and villages, they spread the more advanced technique of agricultural work and craft production, while at the same time disrupting the nationally unified picture of Bohemia and Moravia. In the 13th century, the highest feudal nobility was established, the property of the Church increased and the sovereign ceased from being an exclusive representative of the state. The entrepreneurial burgher arrived at the forefront (Doležel, 2009).

Advances in agriculture accelerated the turn of the feudal economy. The market surpluses revitalized urban agglomerations and new cities were set up. In their walls, concentrated craft and trade, the capacity of the city market has become a determinant measure of the prosperity of the surrounding region, and –in a higher degree– also of the national economy. Larger production opportunities for the city and the village developed bilateral exchanges accelerated by the use of cash currency. This increased the interest of the feudal rulers for cash crops. It was a natural phenomenon of the medieval economy and a dynamic boom in particular to those areas that were upgraded to mass production and at the same time to export appreciated and recognizable products (Doležel 2009).

A city in the late Middle Ages was a self-governing entity with defined right, freedoms and obligations to the population. Unlike the older agglomerations with loose structure, the new cities had designated location for different land uses. The parcels with individual housing or business uses composed the units of each city; their holding after payment of the admission fee and the regular annual taxes entitled the people to the status of a citizen and a member of the municipality with all the benefits and obligations (Doležel 2009).

### 3.1. *The new urban planning systems*

By the end of the 13th century, there was a relatively high number of cases of transformation of the older castle centers in a regular town either on the site itself or in its close proximity. The layout of urban parcels sometimes respected older buildings and main communication axes, but there has been a major overhaul of land according to a regular scheme. The oldest sites of this type are Opava (its urban origins date from 1224), Hradec Králové and Litoměřice (1225) or Znojmo (1226); by the end of the reign of Wenceslaus I in 1253, Žatec, Ústí nad Labem, the Old Town of Prague on the right bank of the Vltava river and, in Moravia, Brno, Hodonín and Olomouc. (Doležel 2009)

The second basic type was a characteristic product of the planned construction of central settlements in

previously unregulated regions. Its ground-plan, did not have to take into account the existing area, was logically stretched to a clear, regular arrangement, but besides the rectangular layout, it was also possible to assemble the structures centered on triangular, lenticular or street-like marketplaces. The additive principle of the parcel composition allowed countless types and size variations; we see large royal towns with a developed street network, and a small town with an over-sized marketplace as more or less the only compositional element. Characteristic examples are České Budějovice (1265), Klatovy (1260–1263) and Vysoké Mýto (1262). The most outstanding examples of this category, Pilsen (1295) and Nový Bydžov (before 1305), come from the years of the reign of Wenceslaus II (1283–1305) which formed a different stage in the urbanization of the Czech lands. This new Wenceslaus city of a strictly geometric scheme belongs to the top performances of medieval urbanism and engineering throughout Central Europe (Doležel, 2009).

## 4. GENERAL OBSERVATIONS AND PRECEDENT CASE STUDIES

The present paper focuses to this second category of urban systems, which form a clear rectilinear grid of intersecting streets, forming in-between them city blocks, with a quadrangular city square consisting of the central blocks of this grid. This led to the selection of fifteen cities among those mentioned in Jiří Kuthan's book *Czech architecture towards the end of Ottokars dynasty*. Drawing up the azimuth diagram for the east–west axes (Figure 1) of these urban systems it was noticed that most of the azimuths have a southwards deviation from the east equinoctial points (Figure 2). Besides this ascertainment, checking the online maps one more important detection was that the churches sanctuaries that are inscribed in these urban layouts face east, but at the same time their longitudinal axes usually do not follow the city grids axes. In the first place, this can lead to two possible explanations. Either they were pre-existing churches and their orientation was not taken in consideration during the realization of the urban net, or that the orientation of the longitudinal axes of these churches carry a different meaning from the one given to the city's grid.

Surveys on medieval and gothic churches' orientation in Europe, showed that primarily their longitudinal axis was synchronized with the equinoctial and solstitial sunrise times, but also with the sunrise time on the feast day of the patron saint. Other possible dates were the foundation or inauguration dates of such buildings (Barlai, 1988).

At the same time, in many studies it was ascertained that urban systems of many major cultures

where very often astronomically orientated. In the ancient Roman empire, the foundation and planning procedures of a new town were explicitly related to the sky. A study of 38 Roman towns in Italy showed that the orientation of the towns is not random. A group of towns were located near the cardinal points, in a sector of around 10 degrees of amplitude on both sides of due east. Another group of azimuths falling between 10 and 19 degrees north or south of east may indicate also important festivals of the Roman Calendar, while there is another group of towns located near the winter solstice sunrise line and few more near the summer solstice sunrise line (González-García & Magli, 2014). Similar study on the orientation of 43 Roman towns in Hispania of various typologies and epochs indicated that orientation was presumably planned according to particular favored directions. The largest group of such orientations were those close to the solstices (González-García et al, 2014).

## 5. METHOD AND DATA

Based on the above and considering that the urban planning systems under consideration were a revival of Roman principles of organization, it was considered important to calculate the declination for

each one of these cities' horizons. The divergence between the equinoctial points and the cities axes could have occurred due to the different heights of the horizon.

Azimuth measurements of the east-west axes of the city grids were performed using the virtual measuring tools of Google Earth. The drawing of the reference lines on the Google Earth maps was repeated 9 times, selecting alternative baselines, as replicate measurements are necessary in estimating the error. We also used photographs from different satellites, to make sure the parallax error is taken into account. In this process, we cross-checked the results with the aerial photographs available from ČÚZK (Czech Geodetic and Cadastral National office), and we tend to agree with the recent results (Rodríguez-Anton et al, 2017) that cadastre photographs are not optimized to conserve angles.

The angular height was calculated with the help of *HeyWhatsThat* website (Kosowsky, 2013), while declinations were calculated with the program *GetDec* (Ruggles, 2013). The results of the above measurements for each one of the fifteen cities are listed on Table 1.

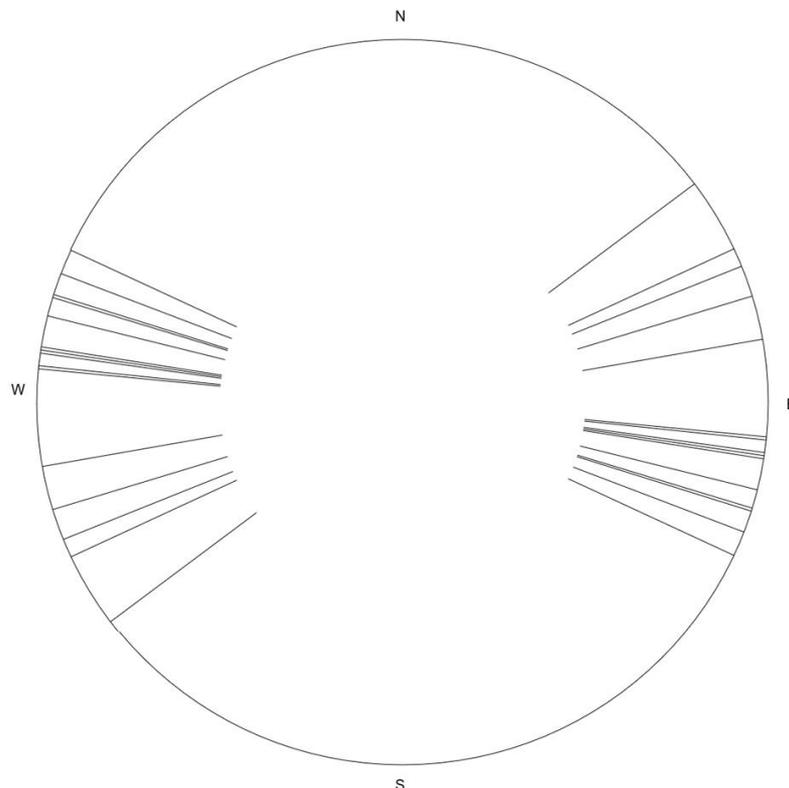


Figure 1: Azimuth diagram of the east-west axis of 15 Czech cities founded in the 13<sup>th</sup> c.

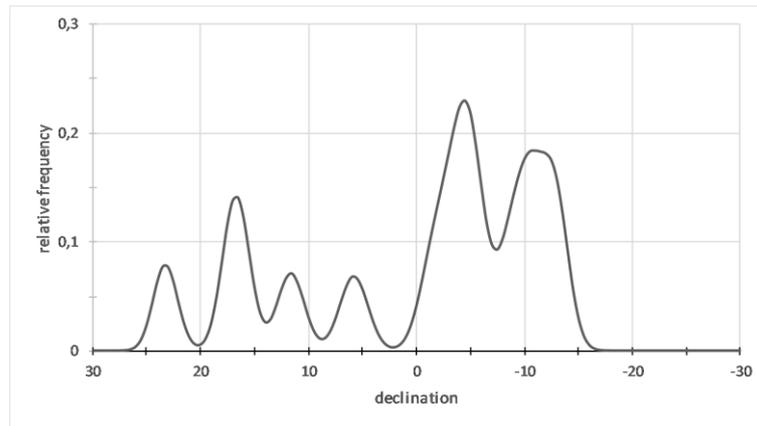


Figure 2: Declination curvogram of the cities under study.



Figure 3. A view just before sunrise on summer solstice 1265 from the town of Beroun. Jupiter is leading, with Saturn, Mercury and Sun following, picturing the forces of the Airy Triplicity. Conjunction of Jupiter and Saturn was about  $1^\circ$  on August 1; on that day the sun rose at an azimuth of  $68^\circ$ . Simulation of the sky using Stellarium 0.18.0 planetarium software.

## 6. RESULTS AND DISCUSSION

After checking the results of our calculations for the east-west axis of the urban grids in question, it is obvious that a homogeneous conclusion cannot be drawn.

In particular Kolín's urban grid was determined in all probability from the flow of the river Elbe as observed on the maps; Vysoké Mýto's and Litovel's urban plan orientation must have been determined in the same manner.

Čáslav has an east-west axis azimuth of around  $53^\circ$  which appears to coincide with the summer solstice sunrise azimuth.

In the year 1265 a conjunction of Saturn and Jupiter occurred as an Air Triplicity, which has Saturn as lord-by-day, Mercury as lord-by-night and Jupiter as partner (Al Biruni, 1029, §445). These two planets used to be known as the rulers of the ages; they are the planets of positive, constructive social activity. Their cycle can be considered the ground base of human development which marks the interaction between Jupiter – perception of ideas, potentialities,

possibilities— and Saturn –their manifestation in the concrete material world— (Baigent *et al*, 1984). This must have been an astrologically favorable time (Fig. 3) to build new towns.

Beroun's azimuth could have been determined by the axis of the church of St. Jacob, located on the west side of the city's main square. In such case the east-west axis of the city would have  $57^\circ$  azimuth. Checking the maps of the area is apparent that the city is built along a pre-existing road connecting Prague with Pilsen, and it served as a main stopover between these two major centers. But the city's orientation of  $68^\circ$  points to the sunrise on 1 August, when the distance of Saturn and Jupiter was approximately  $1^\circ$ , a direct reference to the aforementioned important astrological event.

Domažlice has a very pronounced east-west axis; its declination points to the sunrise around the end of March at the time of foundation. Klatovy and Uherský Brod point to the sunrise at the beginning of March on the year of foundation. So, these are not in direct reference to equinox. Declinations of the order of  $-2$  degrees may represent an orientation to

the Orion belt for the period in question. Astrologers considered it of importance as portending good fortune and fleeting public honors to those born under its influence (Allen, 1899).

Five cities from the list (České Budějovice, Klatovy, Nový Bydžov, Uherský Brod, and Pilsen) have a slightly larger deviation from the equinoctial points. They appear to have a divergence of 6° to 8° from geographical east. From their overall urban design, someone would expect a more clear justification of their orientation. The declination results cannot give a clear answer for the use of astronomical methods determining the orientation of these urban systems. On the other hand, the almost similar deviation of the cities azimuths from the equinoctial points creates the suspicion that a compass might have been used to orientate the cities towards the cardinal points. The geomagnetic model CALS3K.2 (Korte and Constable, 2005), for the years around 1270 AD in the Czech lands, gives a magnetic declination of 5 to 10 degrees. This result is a close match with the divergence of the east-west axes of the aforementioned towns.

The first mention of the compass in Europe was Alexander Neckham's account ca. 1187 and by 1269 Peregrinus was undertaking detailed experimental work on magnetism. There is also a reference to the compass in *Las Siete Partidas* (II, 9.28) written at the time of Alfonso X (Southey, 2015). Ali & Cunish (2001) state that the compass could not have been used by church builders before the end of the 12<sup>th</sup> c.

in England, but Abrahamsen (1992) finds that about 1/4 of Danish Romanesque churches were oriented by compass. In the case of 13<sup>th</sup> century Czech towns – taking into account the intellectual environment of the area and era – we think that using the compass, an advanced scientific tool for the times (Lane, 1963), in town planning cannot be ruled out, as it would add prestige to both engineers and kings.

## 7. CONCLUSION

The implementation of new urban systems in the Czech lands during the 13<sup>th</sup> century was a remarkable act considering its scale, but also the qualities and diversities of each one of these systems. This network of cities still form the outline of the country to the present day. Their recorded rich artistic and architectural qualities are indicative of the cultural level and bloom that emerged during this historical period in the Czech lands. Our investigation adds new possibilities on the way these urban systems were oriented, in addition to the prevailing but potentially inadequate views on the subject. The possibility of having been orientated with the help of astronomical and physical methods was examined with the help of online virtual measuring tools and applications. The indications cannot lead to clear answers, but still they are encouraging for further on-site investigations, which can give more accurate measurements and consequently more secure conclusions.

**Table 1: Orientation data for 15 Czech cities founded in the 13<sup>th</sup> c. D stands for the year of foundation or first mention;  $\varphi$  for latitude;  $\lambda$  for longitude;  $A_z$  for east azimuth;  $h$  for horizon height;  $\delta$  for declination. These cities were selected because they are planned and built within the Ottokars era with a city grid.**

City Name	D	$\varphi$ (°)	$\lambda$ (°)	$A_z$ (°)	$h$ (°)	$\delta$ (°)
Beroun	1265	49.963	14.072	68	3.3	16
Bruntál	1223	49.988	17.464	112	1.7	-13
Čáslav	1264	49.911	15.389	53	0.5	23
České Budějovice	1265	48.974	14.474	99	1.6	-5
Domažlice	1265	49.440	12.929	82.5	1.2	5.5
Jihlava	1270	49.396	15.590	64	0.3	16.5
Kadaň	1261	50.376	13.271	108	0.8	-11
Klatovy	1260 – 1263	49.395	13.295	94.5	1.9	-2
Kolín	< 1261	50.028	15.200	110.5	0.0	-13.5
Kouřim	1261	50.003	14.977	72	0.2	11
Litovel	1253 – 1278	49.701	17.076	104	0.7	-9
Nový Bydžov	1305	50.241	15.490	99	0.4	-6
Pilsen	1295	49.741	13.382	98	1.0	-4.5
Uherský Brod	1271	49.025	17.647	96	1.2	-3
Vysoké Mýto	1262	49.953	16.161	107	1.0	-10

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