Додаток 4

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DENDROCHRONOLOGICAL DATING OF THE AQKERMAN FORTRESS PRELIMINARY RESULTS

In 2008 the Malcolm and Carolyn Wiener Laboratory for Aegean and Near Eastern Dendrochronology at Cornell University in cooperation with the Institute of Archaeology of the National Academy of Sciences of Ukraine took reconnaissance of the Aqkerman Fortress and its wooden constructions. The main tasks were:

- assessment of timbers, their quality, accessibility and suitability for dendrochronology;
- collection of samples from several components of the fortress and fortifications;
- development of chronologies for the primary wood species used for construction;
- relative dating of different elements;
- survey of chronologies from neighboring regions;
- absolute dating.

The building technique at the fortress was favorable for the tree-ring study. Stone walls were filled within a framing system of beams, which are still partly preserved. Some of these beams were accessible allowing collection of samples. In some parts of the fortress numerous whole-beams are visible, and a few of them have beam-ends exposed. Access to them was difficult but sampling was possible.

Sampling was carried out in July 2008. The first season of tree-ring study of the Aqkerman Fortress yielded 57 samples taken in the form of wood slices and cores. Location of collected samples is shown in fig. 4.1. Prior to further analysis it was important to identify the wood species used in the construction of the fortress. Different species represent different responses to the same climate factors, and initially samples representing the same species were analyzed. Wood identification based on features of its anatomical structure was performed by means of microscopic methods. The majority of samples were confirmed to be oak (*Quercus* sp.), three samples represented elm (*Ulmus* sp.), and four others were conifers (*Picea abies* and *Abies alba*). All these species are classified as useful for dendrochronology.

The tree-ring structure of the samples was favorable for dendrochronology. Most of the timbers used for construction came from regular and slow growing trees. This means that the samples chosen for study have sufficient (>80) number of tree-rings to expect positive results from tree-ring dating.

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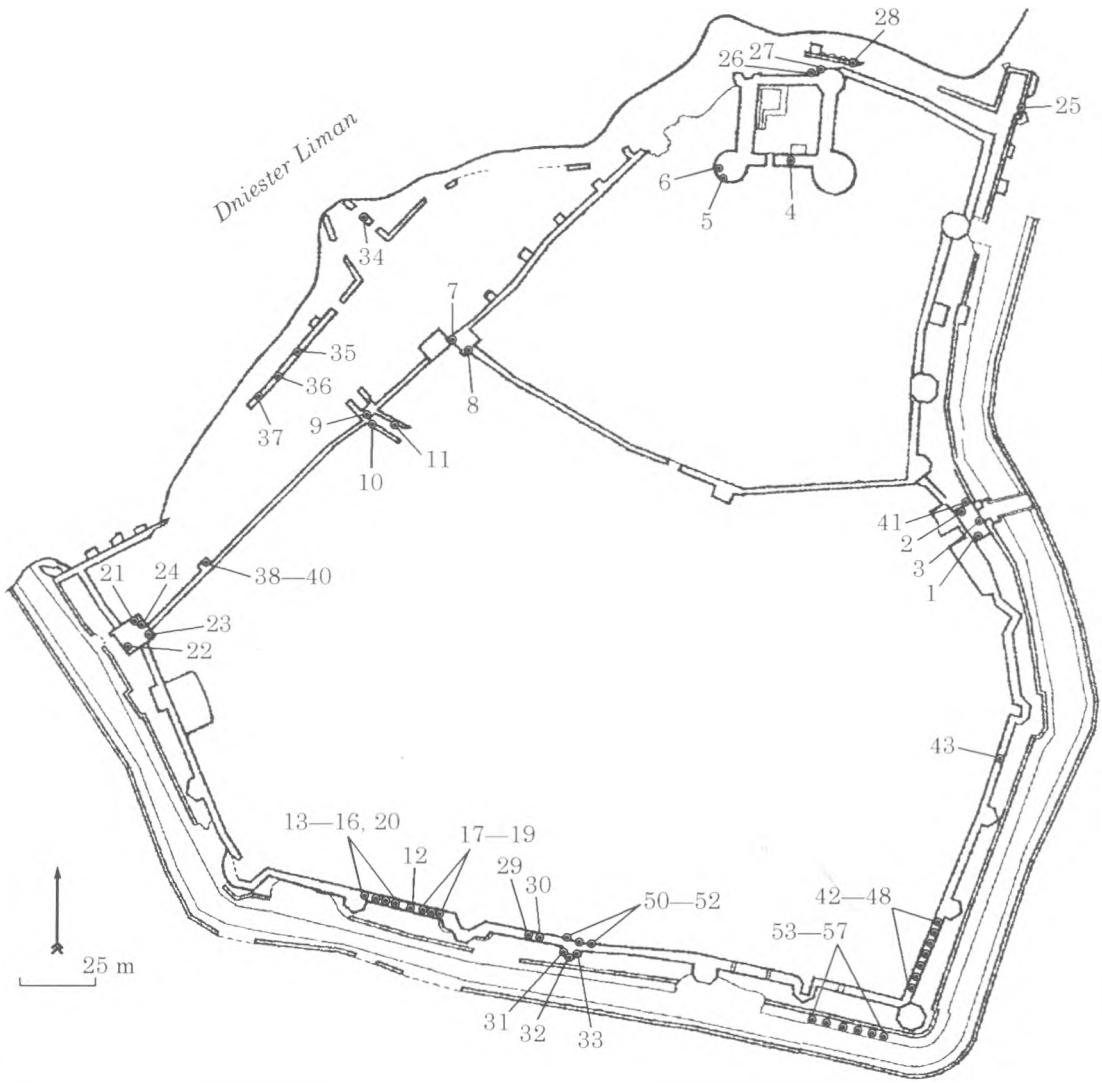

Fig. 4.1. The Aqkerman Fortress. Location of samples collected in July 2008

Samples were prepared in the laboratory to expose the tree-ring boundaries. Different methods of preparation were applied depending on wood structure, from polishing by sanding machine to cleaning by razor blades. Next, samples with clearly visible tree-ring structure were measured using the LINTAB platform and the light microscope ZEISS Stemi 2000. Tree-ring widths were the measured parameter, 0.01 mm was the precision of measurement. Tree-ring series were registered by means of TSAPWin system.

The procedure of dendrochronological analysis requires three steps. The first is to compare tree-ring series representing different radii of the same timber to verify quality of measurement and to assess possible growth anomalies. The next step is to cross-date samples within the same building structure to each other. This ensures grouping of timbers representing the same period and geographical origin, and creates chronologies from internally dated series. Such «floating» chronologies are finally cross-dated against the absolutely dated master chronologies.

Cross-dating was performed using TSAP-Win (Rinn 2005), CORINA (Harris, Hamid, madar and Brewer, 2001—2008), DENDRO for Windows (Tyers 2004) and CATRAS (Aniol 1980—2003) systems. Cross-dating allows us

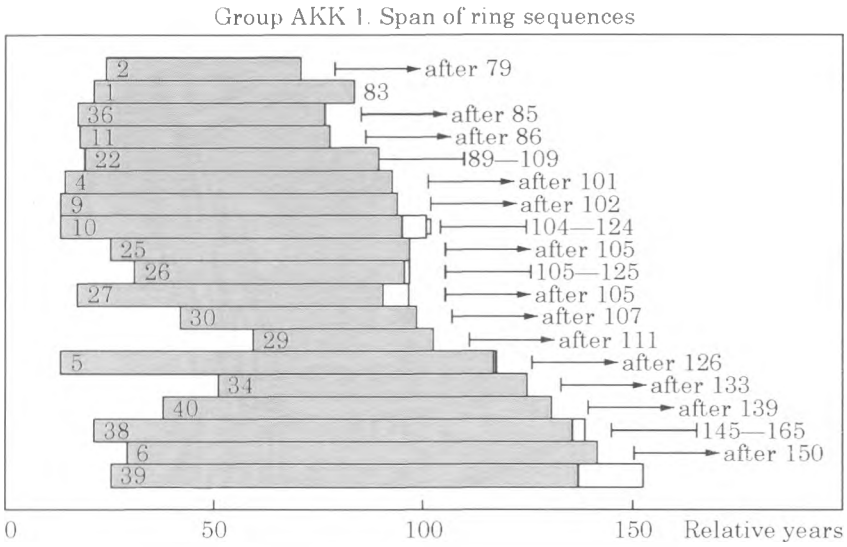

Fig. 4.2. Relative dating of tree-ring sequences representing pattern 1. Bar diagram shows location of tree-ring series representing samples (numbers on the bars) in time. Axis «X» reflects relative years. End of bar shows the date of the last (youngest) existing ring. Diagram contains also interpretation based on existing or added sapwood rings. Sapwood is the outer part of a trunk, brighter in the case of oak. Only this part of tree participates in the life of a tree. The darker, inner part has only mechanical functions. Preliminary number of sapwood rings in the range 10—30 was used for estimation of missing sapwood rings. For samples without sapwood, only «*terminus post quem*» can be given

to place sequences in time by matching the patterns securely, using statistical tests to suggest possible relationships. Every positive result of statistical correlation was verified visually by comparison of graphs reflecting the growth rhythms of the trees.

Results. Tree-ring examination of the collected timbers delivered 35 dating results as of April 2009. All relatively dated samples were divided into two groups representing different tree-ring patterns, according to the distribution of results and observation of the tree-ring structure, especially the exterior rings of each sample (fig. 4.2).

Group 1 is chronologically more diverse (fig. 4.2). Timbers belonging to this group were found in the Citadel, Fisher Tower, Great Gate, Water Gate, Entertainment Tower, rectangular Tower 21, Barbican, and in the structure of the southern curtain wall, close to the Arsenal Building (fig. 4.3). Tower 21, SW circular tower of the Citadel, and the Water Gate are ca. 30—40 years younger than other timbers representing this group.

The group of timbers representing the second tree-ring pattern is very homogeneous (fig. 4.4). Timbers are from the same forest stand and from trees standing close to each other. All oaks were ca. 80—120 years old. Probably these timbers represent one felling campaign. They were found in the bottom of walls surrounding the Civil Yard at the height from 2 to 7 m above the ditch (timbers 53—57) as well as in crenellations between the Storeyed Tower and Tower 10. They were also found in the structure between the White Tower and Tower 16, which was originally identified as a canon platform. A single beam found inside the structure of the outer wall standing directly on the cliff just outside the southern wall of the Citadel is also contemporary with these structures.

Correlation between both groups of timbers was not found. There are three possible reasons for this:

a) both groups represent different periods, and the tree-ring sequences do not overlap;

b) different geographical origins of timbers result in two different tree-ring patterns;

c) case a) and b) occurring simultaneously.

The Aqkerman Fortress is situated on Dniester liman, an estuary of the Dniestr River as it flows to the Black Sea. Such a location invites several possibilities for the delivery of construction materials, depending on raw material resources and the actual political situation of the time. Therefore, in order to find absolute dating, the origin of the timbers needs to be taken into consideration. The steppe environment around the Aqkerman is an unlikely provider of the high quality oak found in the fortress. Transport of oak timbers from Moldavia or West Ukraine by the Dniepr River seems to be the most logical method; however,

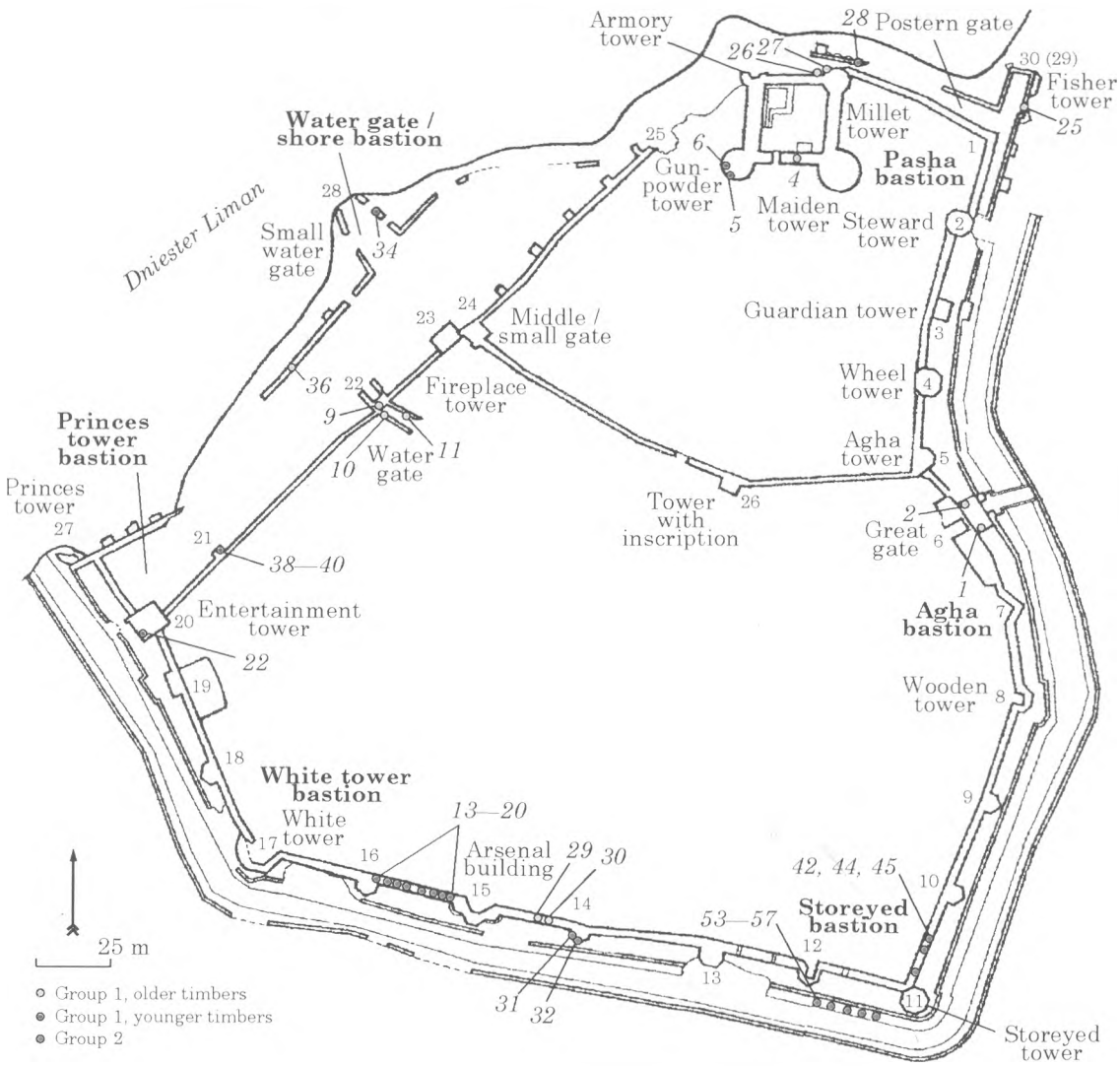

Fig. 4.3. Map of the Aqkerman Fortress with location of dated timbers (circles). Numbers of timbers are in *italic*

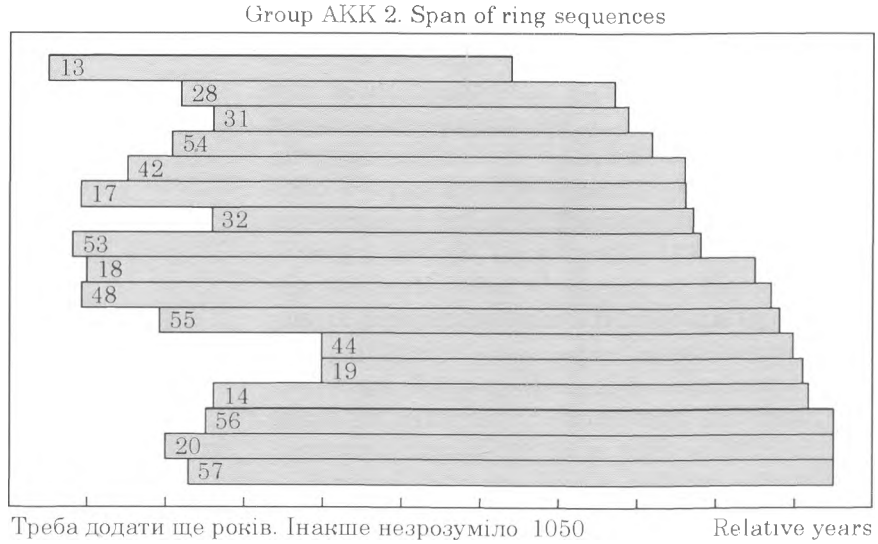

Fig. 4.4. Relative dating of tree-ring sequences representing pattern 2

importation from more remote regions is also possible. The big river systems of the Danube and Dniepr provide optimal conditions for long-distance transportation. Ottoman builders could theoretically have used oak from the southern Black Sea rim.

A survey of the existing tree-ring chronologies for oak in geographic regions around Bilhorod-Dnistrovskyi revealed that we can expect absolute dating. The oak chronology for Ukraine constructed by Kolishchuk covers the period AD 890—1985. Looking to the West there are Romanian chronologies: Maramures (by Eggertson, unpubl.) and Transylvania (by Botar, unpubl.), which collectively cover the period AD 1410—19 98. In the Northwest there is a chronology constructed for southeastern Poland ranging from AD 1100—1997 (by Krapiec, unpubl.) and unpublished site chronologies built by Wazny. The Black Sea region is represented by a chronology built for the southern coast and covers the period AD 1081—2004 (Griggs et al. 2007).

Tree-ring study will almost never give dating results for all analyzed samples. In the case of the Aqkerman timbers only 35 samples so far have produce results. This may be due to:

a) tree-ring sequences that are too short; usually 50 rings is an absolute minimum to qualify a sample for dendrochronology;

b) trees growing with individual growth factors. Trees are living beings and their growth reflects mainly climatic conditions, but sometimes very local environmental disturbances, individual growth disturbances (insect attack, fungal disease), or genetic modifications;

c) some samples could be not cross-dated to the other samples because of different origins, time periods, etc., as stated above;

d) unknown reasons (unexplained factor «X»);

e) a ratio of 60—70 % of samples dated is considered fully satisfactory.

Only relative dating could be achieved as of April 2009. Detailed study of timbers containing sapwood or sapwood / heartwood boundary will be performed to refine results. In the next step of data processing two chronologies representing the Aqkerman timbers will be compared with all existing regional chronologies to obtain absolute dating. However more samples are needed. Some structures (the Fisher Tower for example) are represented only by a single sample. Extension of the oak chronologies is also necessary to provide possibilities for dating undated timbers. The probability of absolute dating increases with increasing length of tree-ring sequences. Therefore on the basis of work done in 2008 the next sampling action will be performed in summer 2009. New samples will provide new dating possibilities also for undated timbers.