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METALLOGRAPHIC ANALYSIS OF IRON OBJECTS FROM CASTLE BRONKA, TRANSKARPATHIAN UKRAINE

Introduction. Long Medieval period covered also many changes and developments in economy, in techniques and technologies of production processes. It is very important to study the hints and conditions of changes in industrial technologies leading to highly effective modern techniques and technologies in present. In the field of ferrous metallurgy, smelting technologies at the beginnings of Medieval were performed in small shaft smelting furnaces with yield of about 10 kg. The last phase of Medieval was characteristic by work of first charcoal blast furnaces (Mihok, 2006, p.173-184). It was giant step, from small "pocket" metallurgy to mass production. How the development advanced? What was the spread of technologies in larger geographic regions? To answer these and many more questions, it is necessary to study collections of Medieval finds related to production and working of iron.

Excavations of Medieval castles and towns produce usually rich collections of ferrous metallurgy finds, i.e. smelting and smithy slag, parts of furnaces, iron objects, equipments of smithies. Author of this paper studied a lot of such collections from Slovakia (Mihok, Lavrinčíková, Bereš, 2005, p.143-180; Mihok, Čaplovič, 1993, p.44-45; Jenčová, Mihok, Briančin, 1995, p.265-278; Mihok, Roth, 1997, p.183-192; Mihok, Pribulová, Labuda, 1996, p.287-306; Mihok, Vargová, 2003, p.67-96), Czech Republic (Mihok, Pribulová, Unger, 1999, p.115-131) and Italy (Mihok, Pribulová, La Salvia, 1999, p.192-212). Research of ferrous metallurgy finds from Transcarpathian Ukraine Medieval castles and towns has just started (Mihok, Prochnenko, 2008, p.149-165). Because of importance of such evaluation the study of iron objects from castle Bronka, described in this paper, is the next step to cover the very important part of Transcarpathian Ukraine industrial history.

Archaeological situation. Archaeological expedition of the Uzhgorod National University in spring 2008 made excavations of the castle situated south-east of village Bronka, Irshava district, Transcarpathian Ukraine. The castle is situated on the tip of steep hill named Tzar hill, flown round by the river Rika. Small castle (30 x 15 m) consist of two buildings: round guarding bastion and habitable house.

The finds from excavations (ceramics, metallic objects) enabled to date the stone walls to the end of the XIIIth century A.D. and main horizon of the castle existence to the first half of the XIVth century A.D. A small group of ceramic finds was dated to the XVth century A.D.

Five metallic objects were selected for metallographic analysis. They were dated to the period of the castle existence, end of the XIIIth - beginning of the XVth centuries A.D. One of the objects, iron strake covered by lead, was dated more exactly to the XIVth century A.D.

Methods of metallographic analysis. Five iron objects found in the Bronka castle site were selected for metallographic analysis. Three of them, object no.1 - fighting knife, object no.2 - strake, object no.5 - nail, were in original state, next two, objects no.3 and no.4 - knives, were in fragments. The samples from the objects were taken with the help of a saw. Next the samples were mounted in mounting resin and metallographic surfaces were prepared by grinding and polishing. The surfaces were observed under metallographic optic microscope first in non-etched, next in etched states. As an etching agent nital (solution of nitrid acid in alcohol) was used. Interesting features observed on metallographic surfaces both in non-etched and etched states were photographically documented.

Results of metallographic analysis. *Sample 1. Fighting knife.* The object no.1, fighting knife, is in Fig.1. The method of sample taking is shown in Fig.2. The sampling method allowed to observe and study both edge and body of the knife. The sketch of analysed metallographic surface is in Fig.3. The numbers in the sketch mark the spots where different structures were observed.

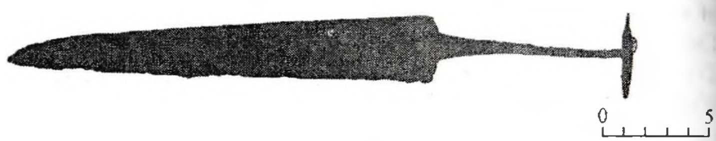

Fig.1. Object no.1. Fighting knife.

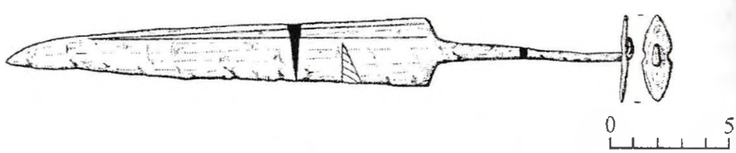

Fig.2. Object no.1. Fighting knife. Method of sample taking.

Fig.3. Object no.1. Fighting knife. Analysed metallographic surface.

Bands of smithy inclusions and bands of scales were observed on the metallographic surface prior to etching (Fig.4). Etching revealed only ferritic structure of non-carburised iron in the body of the knife (Fig.5, spot 1). Down to the edge deep surface carburisation appeared (Fig.6, spot 2). Fig.7 shows metallographic surface near the edge, where carburisation of both surfaces is visible (spot 3). Metallographic surface of the very edge, spot 4, is in Fig.8.

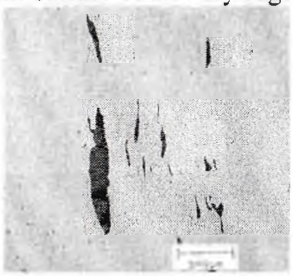

Fig.4. Smithy inclusions in sample 1.

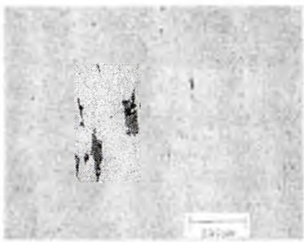

Fig.5. Ferritic structure of non-carburised iron in spot 1. Sample 1.

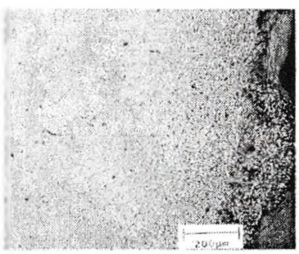

Fig.6. Deep surface carburisation in spot 2. Sample 1.

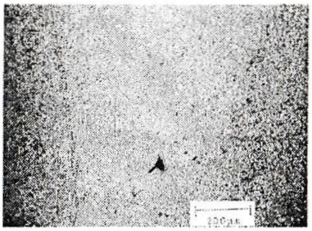

Fig.7. Deep carburisation on both sides of the metallographic surface. Spot 3. Sample 1.

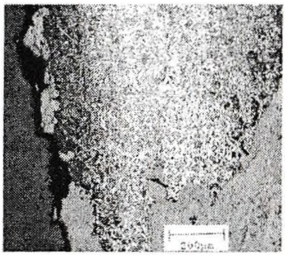

Fig.8. Structures on the edge of the knife. Spot 4. Sample 1.

Fighting knife was produced from non-carburised iron. Next, after reaching the final shape, the edges of the knife were deep carburised. Such production method was very suitable for massive weapon like fighting knife. The knife had tough body that resulted from use of non-carburised iron and hard edges, result of deep carburisation.

Sample 2. Strake. The object no.2, strake (of a wheel) is in Fig.9. The sample was taken from the arm of the object (Fig.10). The sketch of analysed metallographic surface is in Fig. 11. Bands of smithy inclusions and bands of scales were found on non-etched metallographic surface. One band of smithy inclusions (Fig.12), stretched from one side of the metallographic surface to the other, as depicted in Fig.11. Probably it was the place of welding of two iron semi-products during production of the strake. Etching revealed fine grained ferritic-pearlitic structure of low carburised iron on bigger part of the metallographic surface. This very uniform ferritic-pearlitic structure was separated by band of smithy inclusions from middle grained ferritic structure of non-carburised iron on smaller part of the surface. Boundary between the two structures with the band of smithy inclusions is in Fig.13, spot 1.

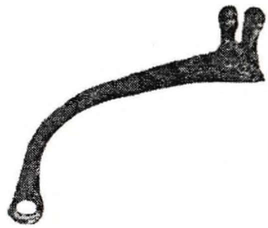

Fig.9. Object no.2. Strake.

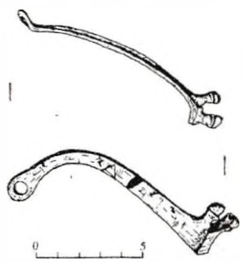

Fig.10. Object no.2. Strake. Method of sample taking.

Fig.11. Object no.2. Analysed metallographic surface.

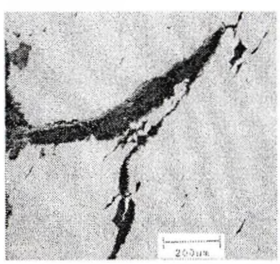

Fig.12. Band of smithy inclusions on the metallographic surface of sample 2.

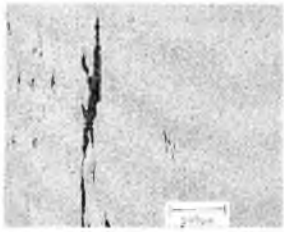

Fig.13. Structures in spot 1. Sample 2.

The strake (of a wheel) was produced by welding of two iron semi-products made of non-carburised or low carburised iron. Iron of this kind with tough properties was fully suitable for production of strake. Very uniform structures found on both parts of the metallographic surface demonstrate high skills of the local blacksmiths, producers of the strake.

Sample 3. Knife. The object no.3, fragment of a knife, is in Fig.14, the way of sample taking is depicted in Fig.15. The sample was taken from the end of the fragment and covered whole cross-section from the back to the edge of the knife. The sketch of analysed metallographic surface is in Fig.16.

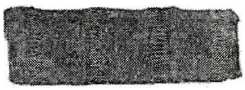

Fig.14. Object no.3. Fragment of knife.

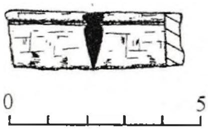

Fig.15. Object no.3. Fragment of knife. Method of sample taking.

Fig.16. Object no.3. Fragment of knife. Analysed metallographic surface.

Only a few particles of smithy inclusions and scales were found by observation of the metallographic surface in non-etched state. One bigger particle of scale is shown in Fig.17. Etching visualised very interesting distribution of different structures. The back of the knife, spot 1, was deep carburised to about 0,7 - 0,8% C (Fig.18), with resulting pearlitic structure. As can be seen from the Figure, pearlitic structure gradually changed to pearlitic-ferritic structure with lower carbon content. It documented carburisation of the knife back, not welding of the pre-prepared carburised iron semi-product on the knife back. Down in the knife body towards the edge ferritic structure of non-carburised iron prevailed (Fig.19, spot 2), but in one side of the metallographic surface one place with deep carburisation, documented by pearlitic and pearlitic-ferritic structures was found (Fig.20, spot 3). Area of the edge was deep carburised, as documented by pearlitic structures. Fig.21, spot 4, shows increase of carbon contents toward the very edge. The structures on the very edge are martensitic (Fig.22, spot 5) documenting quenching of this deep carburised part.

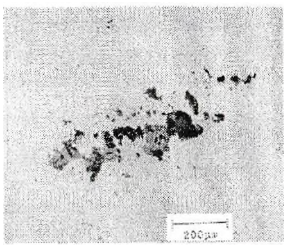

Fig.17. Scale particle on the metallographic surface of sample 3.

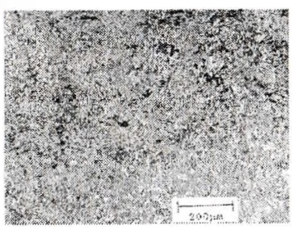

Fig.18. Deep carburisation in spot 1. Sample 3.

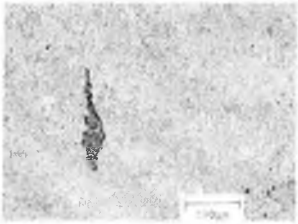

Fig.19. Ferritic structure of non-carburised iron in spot 2. Sample 3.

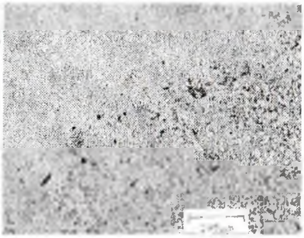

Fig.20. Carburisation by one side of the metallographic surface. Spot 3. Sample 3.

Fig.21. Deep carburisation near the edge. Spot 4. Sample 3.

Fig.22. Martensitic structure after quenching on the very edge. Spot 5. Sample 3.

Utility value of the knife was very high. The sense of the knife back carburisation is not clear, but non-carburised iron in the knife body and deep carburisation of the edge with subsequent quenching led to production of perfect knife with very hard edge.

Sample 4. Knife. The object no.4, fragment of a knife, is in Fig.23, the way of sample taking is shown in Fig.24. The sample was taken from the end of the fragment with hope to study distribution of structures of the whole cross-section. Unfortunately, the fragment was corroded in such extent, that only a few places with solid iron remained. The fact obstructed any serious study of the knife construction method. The structures of two different pieces of solid iron, that remained in corrosion products, were observed after etching. One of them, shown in Fig.25, presents carburised iron with about 0,3% C, resulting in ferritic-pearlitic structures. The second one, shown in Fig.26, presents non-carburised iron with ferritic structure. Presence of both types of structures could lead to explanation the knife had non-carburised body and carburised edge. Such construction method of knife was common.

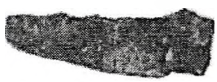

Fig.23. Object no.4. Fragment of knife.

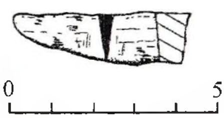

Fig.24. Object no.4. Fragment of knife. Method of sample taking.

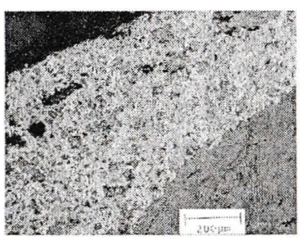

Fig.25. Ferritic-pearlitic structure of carburized iron. Sample 4.

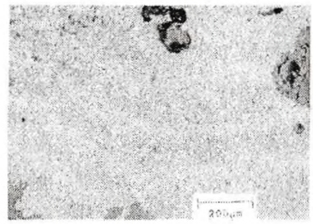

Fig.26. Ferritic structure of non-carburised iron. Sample 4.

Sample 5. Nail. The object no.5, nail, is in Fig.27. The sample was taken by cross-section cut of the nail trunk over the tip (Fig.28). Because of very small object and its partly corroded state it was not sure if the very tip of the nail was preserved. The sketch of the metallographic surface is in Fig.29.

Fig.27. Object no.5. Nail.

Fig.28. Object no.5. Nail. Method of sample taking.

Fig.29. Object no.5. Nail. Analysed metallographic surface.

Observation of the metallographic surface in non-etched state showed very clean iron metal with only one cluster of smithy inclusions. Etching of the sample visualised on the whole metallographic surface only middle and coarse grained ferritic structures of non-carburised iron (Fig.30, spot 1). No traces of carburisation penetrating from the tip were observed.

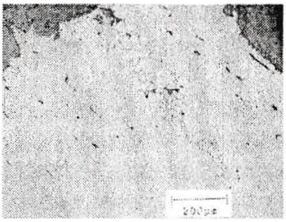

Fig.30. Ferritic structure of non-carburised iron in spot 1. Sample 5.

It was common method to produce nails, objects of consumption character, from non-carburised iron, as toughness was the main quality characteristics of a nail. Many nails were subsequently treated by carburisation of the tips, in some cases also the heads. Because of the corroded state of the analysed nail it was difficult to say if the very tip was carburised or not, but, usually, such small nails were not treated.

Discussion. Five iron objects were analysed in described research. Object no.4, knife, was in very corroded state. This fact did not allow to draw any satisfying results concerning production method of this knife. Next two knives, that were in the analysed set, were suitable for analysis. Though they were not designed for the same use, one of them was fighting knife, the second one was normal smaller knife, their production methods were similar. Both had non-carburised ferritic iron in the body and carburised, in case of the smaller knife also quenched edge.

Such production technology was proper, resulting in knife with tough body and hard edge. The technology was common, found also in analysis of knives from many other Medieval sets of iron objects (Mihok, Vargová, 2003, p.67-96). The knives found in site Banská Štiavnica - Old Town (Mihok, Pribulová, Labuda, 1996, p.287-306) were produced by welding of deep carburized iron semi-product (edges) to non-carburised iron ones (body). Such advanced technique was not found in analysis of the knives from the Bronka castle.

The strake of the wheel was the object under stress during the use. For such situation non-carburised iron material with tough properties was the best choice. In fact, it was the situation found by metallographic analysis of the strake from the Bronka castle.

Many collections of iron objects finds contain also nails. Three main ways of their production were found: 1) production of nail from non-carburised iron material without any subsequent treatment; 2) production of nail from non-carburised iron material with subsequent carburisation of nail tip; 3) production of nail from non-carburised iron material with subsequent carburisation of tip and head of nail. Production method depended on shape and demanded use of nail (Mihok, Pribulová, Labuda, 1966, p.287-306; Mihok, Vargová, 2003, p.[illegible]7-96; Mihok, Pribulová, Unger, 1999, p.115-131; Mihok, Prochnenko, 2008, p.149-165). The nail from the Bronka collection was produced by the first, most common method.

Conclusions. Five iron objects found in excavations of Medieval castle Bronka were submitted to metallographic analysis. The results are as follow.

1. The knives were produces by standard, common method. They were manufactured from non-carburised iron material, next the edge was deep carburised, in case of one knife also quenched. The knives were tough in body and hard in edges. Suitable utility properties resulted from this method.

2. The strake of the wheel was manufactured from non-carburised iron material. Tough properties of the strake were substantial for its use.

3. The nail was produced from non-carburised iron material without any subsequent treatment. It was the most common method used for production of iron nails.

4. The results give evidence about good skills and knowledge of local blacksmiths, comparable with knowledge of blacksmiths from other contemporary Central European sites.

Ключові слова: середньовіччя, замок, археометалургійний аналіз, ковальські операції, виробничий регіон, шпора, ніж.

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Металографічний аналіз залізних речей з Броньківського замку, Закарпатська обл. України
(Резюме)

У польовому сезоні 2008 року археологічною експедицією УжНУ досліджувався Броньківський замок, який знаходиться в Іршавському районі Закарпатської області України. В ході пошуків зібрана колекція залізних виробів, для п'яти з яких був проведений металографічний аналіз. Це два бойові й один кухонний ножі, шпора та цвях, які датуються кінцем XIII - XIV ст. н.е.

Результати аналізу свідчать про застосування різноманітних ковальських операцій при виготовленні даних речей, а порівняння середньовічної технології металообробки на території Закарпаття, Словаччини та Чехії дозволяє вважати їх єдиним виробничим регіоном.

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Металлографический анализ железных предметов с Броньковского замка, Закарпатская обл. Украины

(Резюме)

В полевом сезоне 2008 года археологической экспедицией УжНУ исследовался Броньковский замок, находящийся в Иршавском районе Закарпатской области Украины. В ходе изысканий собрана коллекция железных изделий, для пяти из которых проведён металлографический анализ. Это ножи (два боевых и один кухонный), шпора и гвоздь, датирующиеся в рамках конца XIII - XIV вв. н.э.

Результаты анализа свидетельствуют о применении разнообразных кузнечных операций при изготовлении данных предметов, а сравнение средневековой технологии металлообработки на территории Закарпатья, Словакии и Чехии позволяет считать их единым производственным регионом.

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