

# *Medieval Gunpowder Research Group*



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## **Summary**

A review of our knowledge of gunpowder and its explosive properties has shown just how poor is our current understanding of this most important of inventions. Though this is largely the result of the paucity of contemporaneous documentary evidence it is also due to the lack of good scientific research on black powder. It has also been demonstrated that we have reached the limit to which the documentary and narrative sources can be pushed. However, by using experimental work to explore the ways that these weapons worked has helped us more fully to understand the contemporary sources and to be clearer and more certain of the way that gunpowder and gunpowder weapons developed. A combination of historical research coupled with experimentation and scientific research has been shown to be a potent way forward and enabled us to look more closely than ever before at the original sources, especially those from China, and develop fresh insights into the early development of gunpowder. What is also clear, though, is that this work is only the beginning of a long process to a better and more rounded understanding. Extending the scope to include other researchers and specialists is seen as vital – especially in such areas as international trade and contact between East and West. Similarly building on the experimental work already done, and the failure of the first nitrate bed, is seen as an important way to develop our understanding and skills.

## **Introduction**

Though gunpowder is considered one of the key discoveries of the last millennium, neither its properties nor its early history and development are well understood. Research into its characteristics, especially its rate of burning, was curtailed with the discovery and introduction of modern smokeless propellants in the 19<sup>th</sup> century and there has been little scientific interest in it since then. The study of its early history and development presents particular problems for the historian as there are few contemporary sources and those we have are extremely difficult, impossible sometimes, to understand. This project was set up to initiate a process of interactive research using experimentation as a means to understand more fully gunpowder in all its facets. Questions raised by the historical sources can be addressed by experiment, the results of which can help in our documentary interpretations and so suggest further experimental work and so on.

There are a number of key elements to investigate if we are to gain more insights into medieval gunpowder – including the purity of the saltpetre used, the composition of the gunpowder and the physical parameters under which it was used.

## **Saltpetre and gunpowder**

The discovery of saltpetre in China in around 500AD was the key to the development of gunpowder. From the 10<sup>th</sup> century it was used as a constituent of incendiary devices but when it was used in artillery is still unclear (see below). Just why it took so long for the metal-barrelled firearm to be developed is still controversial but it was probably due, in large part, to the saltpetre that could be made at that time. Unfortunately we have no information about how it was produced in the early period and it is not till European sources of the 14<sup>th</sup> and 15<sup>th</sup> centuries that we get any detailed information of how it was made. The process made use of the ability of naturally occurring bacteria in the soil to break down organic waste products to produce nitrates. These were washed out of the earth of the ‘saltpetre bed’ and isolated and purified by a process of precipitation making use of the differential solubility of potassium nitrate in hot and cold water. The process was not of course carried out to exacting modern standards and indeed the medieval craftsman did not understand in any detailed way exactly what was happening

during the various procedures. The resultant product while it was predominantly potassium nitrate will have contained a number of impurities, for example calcium, magnesium and sodium chlorides and sulphates. What impurities, how much was present and their subsequent effect on the gunpowder made from this saltpetre are all unknown. What is needed is a means to replicate medieval saltpetre as closely as possible.

A reconstruction of a saltpetre bed was set up at the Middelaldercentret in 2002 and saltpetre was extracted using medieval techniques as appropriate. During the work carried out in February to March 2005 the presence of nitrate in the leachate from the reconstructed bed was confirmed, and an estimate of the yield determined, at less than 0.1 g per kg of the product of the saltpetre bed – a very small yield indeed. A small-scale extraction of the expected nitrate was carried out and sufficient precipitate collected for analysis to be carried out. However, analysis revealed that the product was not nitrate but potassium sulphate with just traces of nitrate. The reasons for this probably include:

- Insufficient aeration of the saltpetre bed. The subsequent lack of oxygen slowing down and preventing the breakdown of the ammonium ions by bacteria to nitrates
- Insufficient addition of urine. Although urine was added it is clear that this was not sufficient.
- The use of bird faeces may have been detrimental as they tend to be highly acidic and there is some evidence that the bacteria involved in the breaking down processes are not tolerant of acidic conditions. The addition of lime to the original bed helped in this respect but it may be that insufficient was added.

It is clear however that the potassium conversion process had worked very well.

### **Review of current research**

A review of the literature and current research on gunpowder was undertaken and from this a series of articles was produced (see below). These studies make it very clear that there is much to do in the field of early gunpowder both in the West and the East. In particular it has identified the pressing need for detailed experimental work to identify and quantify the effects and interactions of the various chemical and physical properties of gunpowder. Coupled to this is the need for a test method for the evaluation of gunpowder mixtures which can be used to compare both the various chemical compositions as well as the physical parameters.

Of particular concern is the interaction between chemical composition and physical parameters – grain size and packing density – an area which is vital to our understanding of the various developments in black powder and the way it changed and improved over time. The effect of incorporation, grain size and grain irregularity on burning rate and the pressure generated as well as such areas as the long-term storage of powder all need to be more clearly understood and characterised. Of fundamental concern is the way that the composition of gunpowder, especially its nitrate content, coupled to the packing density on ignition affects the overall burning properties and this needs very careful exploration. Is it possible that very low nitrate powders were capable of propelling a projectile, contrary to what has been assumed, if packed very tightly in a barrel?

A re-evaluation of the material published by Needham on the Chinese sources, undertaken as part of this study has thrown up some anomalies in his analysis and demonstrated that there is a real need to explore the whole field of Chinese fire weapons and their use and effectiveness. In particular Needham's thesis that changes in Chinese practice were linked directly to the nitrate content of the powder mixtures used needs re-evaluation in the light of our cur-

rent knowledge of the burning rate of compressed gunpowder. If we can show that low nitrate powders will explode then his assumption that the first metal-barrelled gun was not developed till the 13th century may be in doubt and its introduction will need to be re-assessed. Though here again the exact composition and nature of the saltpetre used may be a vital factor in some way and only by experiment will it be possible to determine the various factors that need to be explored and evaluated.

This close study of Needham has also led to a growing realisation of the enormous importance of incendiary devices in warfare in both East and West – a type of weapon which has received little modern study of their composition or physical form, nor their use in warfare. In China saltpetre-based burning materials were used from the 10th century while in the West the use of an inflammable liquid, Greek Fire, was developed in the 6th century AD. Both cultures saw the usefulness and effectiveness of the use of fire as a weapon. Even more interesting is that they were used for a very long time. Indeed it is clear from studies of later sources that incendiaries were a feature of European warfare right down to the 17th century and possibly beyond. Part of the reason for this dearth of information is that very few have survived, due of course to their very nature, and that references to their use are not at all common (the notable exception being the account of the Siege of Malta in 1565 where they are noted as being used extensively by the Knights). Only now, with an increased awareness of their importance, have a few examples come to light in collections in Coburg and Stockholm, and from wreck sites such as the Trinidad Valencera, the Mary Rose and the Church Rocks site.

However understanding how these devices worked, especially the classic Chinese incendiary device, the so-called fire lance, is impossible without some form of experimentation. In particular, the descriptions by Needham of their use and effectiveness just do not seem to match what we now know about the burning properties of black powder.

### **Future work**

Of prime importance for a project of this broad international scope is to develop further contacts and stimulate research across the whole breadth of the subject. In particular it is crucial to:

- Investigate the medieval trade in the raw materials, saltpetre and sulphur, as well as in the finished gunpowder.
- Develop contacts within the Chinese, Asian and Japanese academic communities to establish links between this work and any being carried out in China, southeast Asia and Japan
- Develop further research and collaboration with other individuals, groups or institutions, for example with the International Institute for Asian Studies at Leiden University in the Netherlands, the Needham Institute, Cambridge University, Museum Bronbeek, Arnhem, the Netherlands, Firepower, Woolwich, UK, and India.
- Stimulate interest in this field beyond its present narrow confines – in areas such as economic and social history, and international trade.

However it also important to continue the investigation of the properties and characteristics of medieval gunpowder as a means to understand more fully the original sources – both Western and Oriental. Specific areas that require further work include:

- Re-evaluation of the reconstructed saltpetre bed and the establishment of a method which will yield higher levels of nitrates leading to a bed which will produce significant quantities of saltpetre.

- Experimental work and evaluation of the gunpowder made from this ‘medieval’ saltpetre – probably using modern materials to simulate the detailed composition of the salt petre produced from the saltpetre bed.
- Experimental work on the way that the various factors, physical and chemical, interact one with another and affect the burning characteristics of gunpowder.
- Development of a testing procedure for evaluating black powder.
- Experimental work to probe and thoroughly investigate the analysis and assumptions of Needham about nitrate content gunpowder mixtures and whether they will explode
- Experimental work to investigate the manufacture and effectiveness of incendiary devices, especially the Chinese fire lance.

The following articles were written and have been sent for publication

‘The development of gunpowder and guns in China: a critical re-examination’  
Published in the *Journal of the Ordnance Society*, 2011

‘Saltpetre experiments report’  
Published on the Internet

‘Light the blue touch paper and retire’: New research on gunpowder  
Accepted by the *Journal of Explosives Engineers*, September 2005, UK

‘Remember, remember the fifth of November’: New research on gunpowder  
Accepted by *History Today* for publication in November 2005, UK

*Medieval Gunpowder: Problems and possible solutions*