On the possibility of using vitrified forts as anthropogenic analogues for assessment of long-term behaviour of vitrified waste

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The structure of this presentation

1. Introduction
2. Objectives and scope
3. Vitrified waste forms
4. Natural and anthropogenic analogue glasses
5. Vitrified forts
6. Discussion
7. Conclusions

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Glass as matrix for hazardous substances

- Good capability of incorporating various elements in the structures
- Evaluation of the functioning over long times fundamentally difficult
- Necessary to rely on natural and anthropogenic analogues
  - They should be similar in composition and properties, and
  - have been exposed to relevant environments during long times

Three glass waste forms

- Vitrified ash[1] from incineration of domestic waste and similar
- Vitrified contaminated soil
- Vitrified fission products[1] from reprocessing of spent nuclear fuel

(1) Together with additives

Three types of analogues

- Natural glasses
- Glasses in archaeological specimens
- Glasses in vitrified hillforts

Studies so far

- Nuclear waste glass together with natural glasses and archaeological specimens as analogues
- No studies found on analogues in conjunction with vitrified ash and vitrified soil

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Objective and scope

- To evaluate the feasibility of using glass material in vitrified forts as anthropogenic analogues for vitrified waste
- Comparison depends on
  - Composition
  - Process
  - Environment
- => Scope to study composition as well as process

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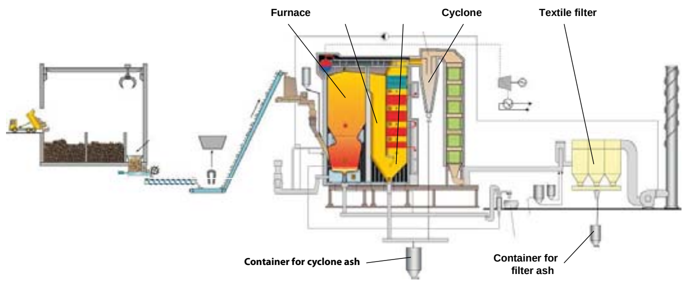
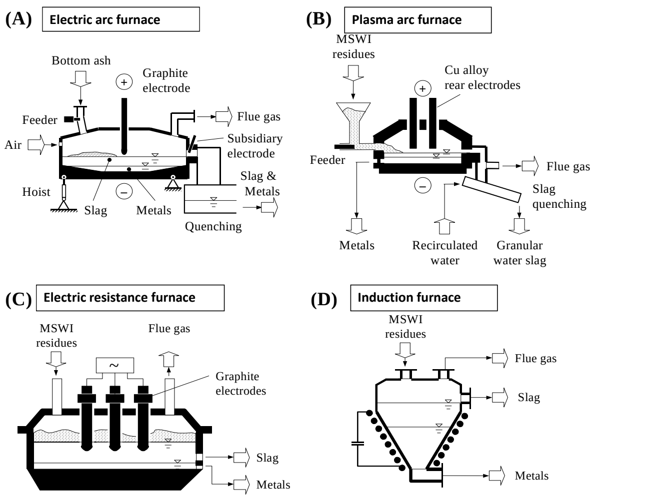
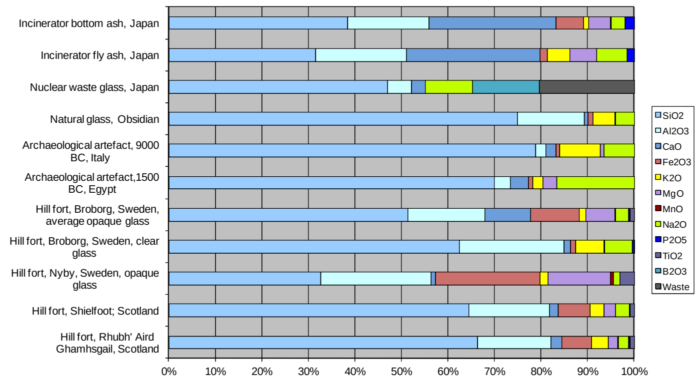
Fly ash and other ashes



Fractional condensation of volatile elements and compounds.
Partial melting of the ash and consequent formation of reactive glass phase





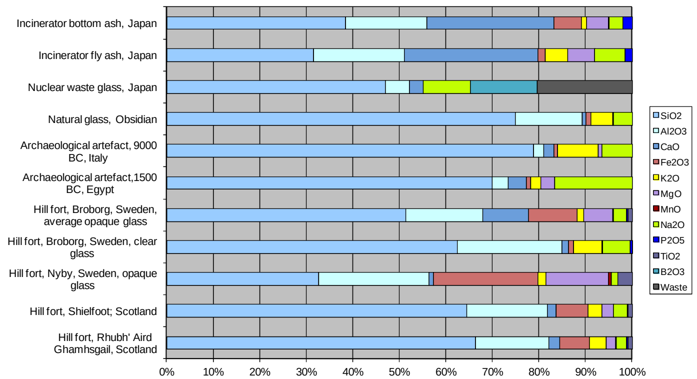
Examples of compositions of various types of glasses.
The compositions are figured as the oxides presented.

Vitrified contaminated soil

- Stabilization in situ of soil contaminated by radioactivity
- The soil is made electrically conducting by introducing a current through a track of graphite, thus heating the adjacent soil to such temperatures that it starts to melt.
- Such partially melted soil contains ions that conduct electricity, and thus the process is made to escalate.

Vitrified nuclear fission products

- The spent nuclear fuel is dissolved and the fission products are separated.
- They are then heated together with additives to form a glass that constitutes a durable waste form in the intended environment.
- Nuclear waste glasses differ considerably from other waste glasses by their loading of fission products and by their high content of phosphorus



Examples of compositions of various types of glasses. The compositions are figured as the oxides presented.

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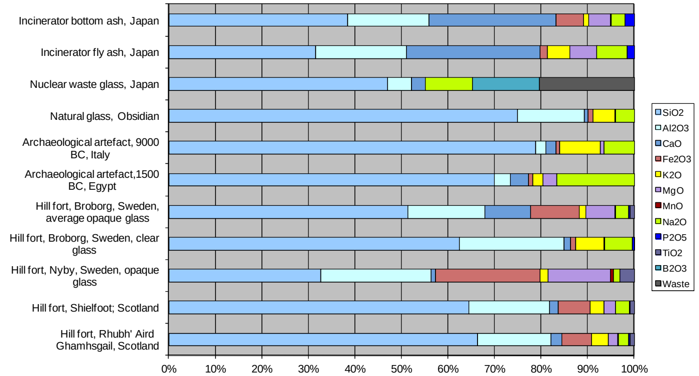
Natural glasses - Obsidian

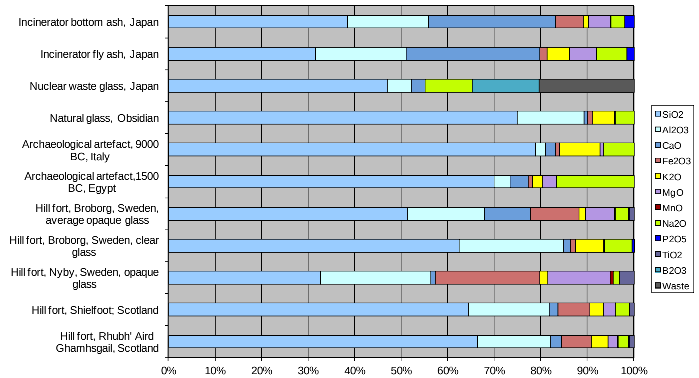
- Formed from lava when cooled relatively rapidly
- Used in the neolithic era in areas where flint was not available
- Studied as analogue to nuclear waste glass



Examples of compositions of various types of glasses. The compositions are figured as the oxides presented.

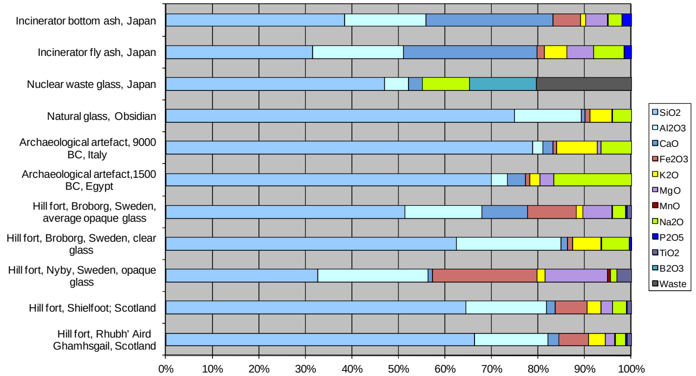
Archaeological glass artefacts

- Most of the glasses prepared from potash and quartz sand
- High content of Na and K ⇔
  - Easy to melt, but also
  - Susceptible to corrosion
- Egyptian glasses high in Na due to use of natural soda



Examples of compositions of various types of glasses. The compositions are figured as the oxides presented.

Broborg near Stockholm, Sweden



Glasses in vitrified forts show a large variety in chemical composition, between different forts as well as within a single fort.

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Vitrified forts

- A fortification made of stone and earth, and usually also logs
- They date from 1000 BC to 1400 AD
- There are up to 30 000 hillforts in Europe
- Around 200 are vitrified forts, and around half of them in Scotland (17 in Sweden)
- Two kinds of “vitrification”
  - Melted rock
  - Calcined rock

Cowdenknowes in N England

Cowdenknowes in N England

Anwoth in SW Scotland

Broborg near Stockholm, Sweden

Broborg near Stockholm, Sweden

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Comparison of chemical composition - obsidian

- Natural glass obsidian much higher in Si + Al and much lower in Na + K than waste glasses
- ⇔ more durable & may show different corrosion mechanisms compared to waste glass

Comparison of chemical composition – archaeological artefacts

- Archaeological artefacts much higher Na + K or Na than waste glasses
- ⇔ less durable & may show different corrosion mechanisms compared to waste glass

Comparison of chemical composition – glass from vitrified forts

- Glass from vitrified forts show large ranges of variation of various elements
- Ranges appear to cover those of the waste glasses with the exception of phosphorus in nuclear waste glass
- ⇔ may show similar corrosion mechanisms compared to waste glass

Quality of heat considerations

- Century long dialogue regarding reason for vitrification
  - To join the stones & make structure strong and durable (especially compared to reinforcement by logs), or
  - As a result of enemy destruction and fire
- Quality of heat ⇔ energy supplied at peak temperature (not total heat in a huge wood fire)
  - Preheating
  - Charcoal instead of wood
- Conclusion that charcoal infilling between the stones may be sufficient for the melting observed (see paper for details)

Method used for vitrification

- Properties depend not only on composition but also on manufacturing process
- E. g. rate of cooling important
- => warranted to analyse ancient process used & compare with modern processes
- Feasibility of "charcoal hypothesis" above can readily be tested

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Conclusions

- Vitrified stone in a large number of hillforts constitute good analogues for vitrified waste
- Compositions vary considerably so that the ranges of parameters cover those of the waste glasses for most major elements
- Quality of heat analysis has lead to conclusions on type of method used => appears possible to reproduce ancient method & validate comparison with waste glass
- No record found on the types of studies mentioned above