Traits of Iron Making Technology in Ancient Korea

Lee Nam Kyu(Hanshin University)

< Table of Contents>

Ⅰ. *foreword*

1. *Background*

The lack of research about ancient iron making

-> recently important iron making sites were increased in middle area of korean peninsular

2. *Purpose*

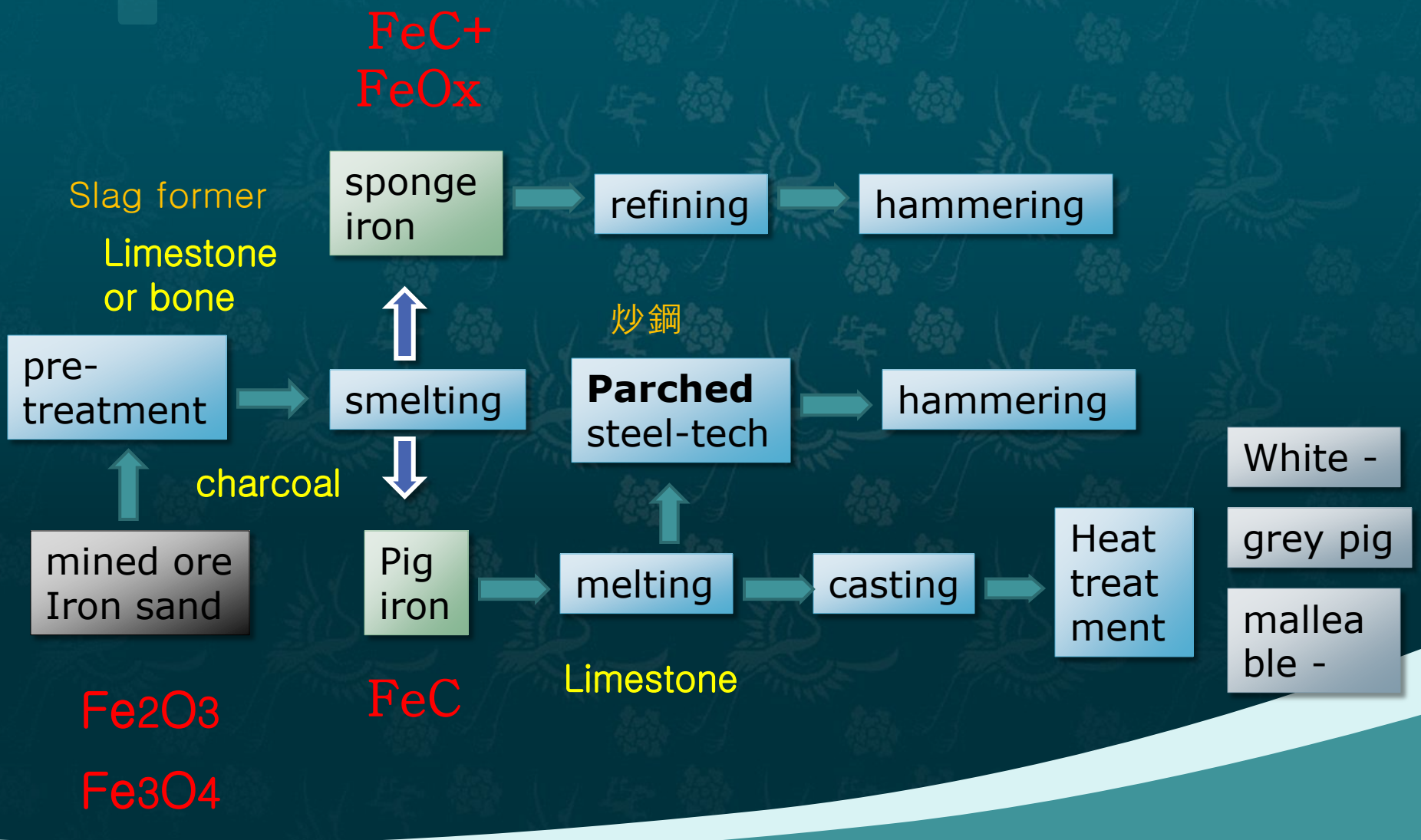
understanding of development of iron making culture from proto three kingdom age(原三國時代)

to the first stage of Paekche(百濟 : A.D.3C~660)

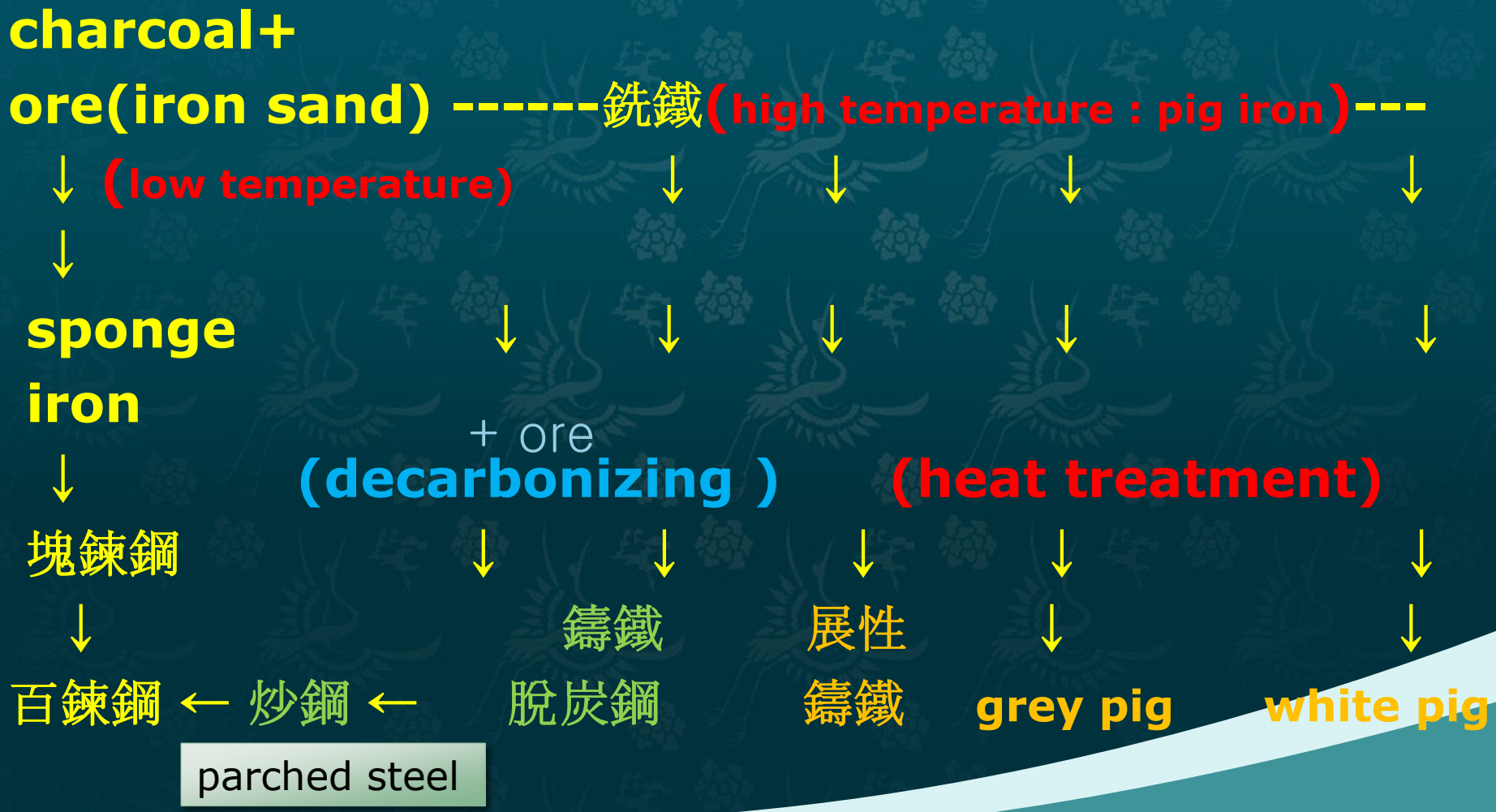
3. *Important contents - epoch-making development*

enlargement of iron making base and introducing of Parched steel technology 炒鋼

Process of iron and steel making in ancient korea



process of iron making in ancient china (李衆 1974)



- 鑄鐵 脫炭鋼: **decarbonized steel from pig iron**
- 展性 鑄鐵 : *malleable* **pig iron**

The division of archeological time in ancient east asia

(中國) paleo-Neolith-夏. 殷--西周--東周(春秋-戰國)-秦-漢-三國- 魏 晉

초기철기 원삼국 삼국시대

(韓國) Paleo--Neolith-----Bronze----Early-Proto---Three---
iron three kingdom
kingdom

(日本) 先土器-繩文(죠몽)----------彌生(야요이)----古墳

(B.C.10.000)------B.C.1000-----B.C.300-----A.D.400--

Ⅱ. Iron Making Culture in Proto-three Kingdom Period (B.C.100~A.D.300)

* Early iron age : no iron making site

1. Hammering site in settlement
- producing(from base settlement)

Distributing to neighbor settlememt

精錬鍛冶(refining site)
Donghae Sonjeongdong(big site)

鍛錬鍛冶(hammering site)
Gapyung Mazangri, Daeseongri, Hanam Misri, Youju Yunyangri , whaseong Giannri

2. Process of iron making and distribution

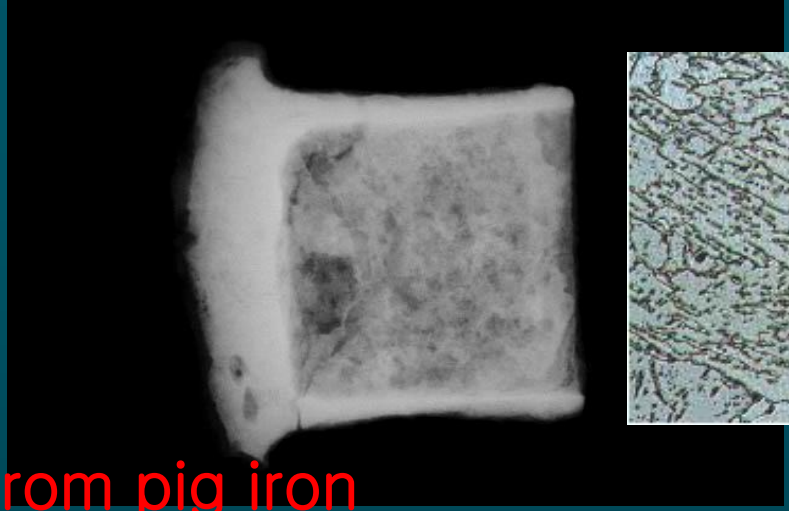
A. Process of hammered steel

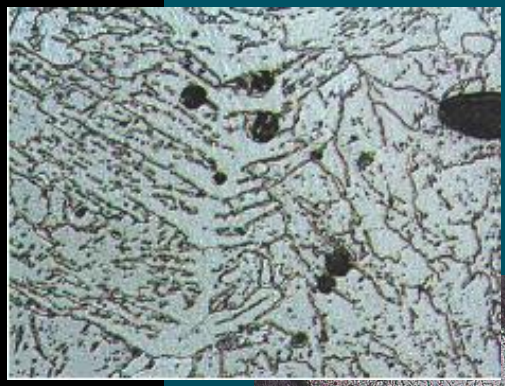
Smelting →distributed to big site → Refining(정련) → Hammering

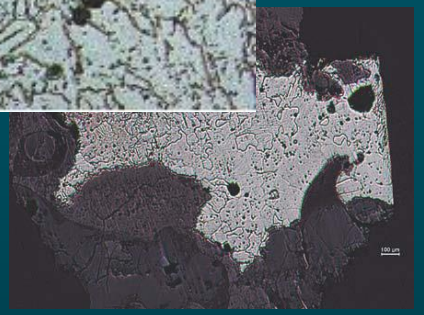
B. Process of casting iron

Produced at the big(central) site →

* Distributed to wide area







decarbonized steel from pig iron

주철탈탄강 조직

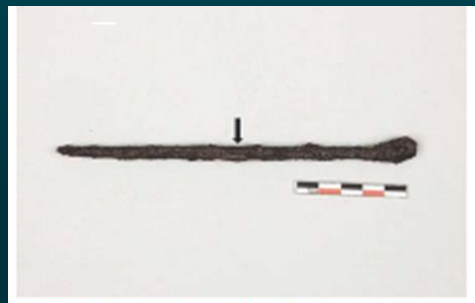


사진 10. 철기 외형과 시편채취 위치

사진 11. 철기 X-ray photograph

괴련철

Iron artifacts made of sponge iron

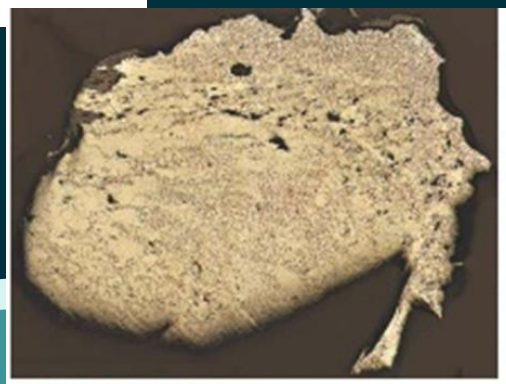


사진 12. 철기 전체조직

사진 13. (사진 12) 상부확대

Iron artifacts made of sponge iron

사진 10. 철기 외형과 시편채취 위치

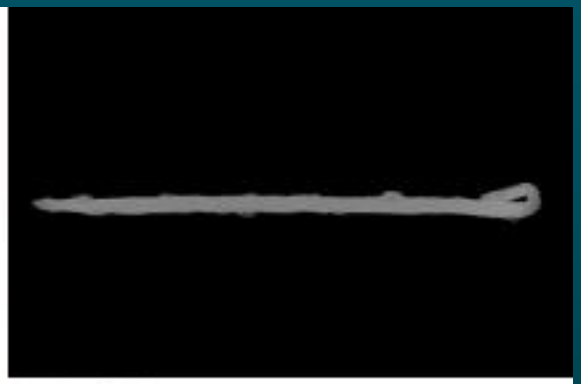


사진 11. 철기 X-ray photograph

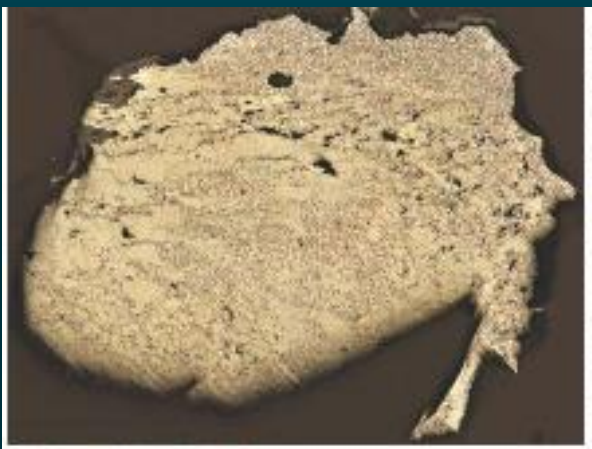


사진 12. 철기 전체조직

사진 13. 〈사진 12〉 상부확대

괴련철

The meaning of Gianri iron making site

(1)Group : smith group from Lo-lang(colony of Han dynasty)

(2) Characteristics

A. Technology of parched steel(炒鋼)

∵ Lo-lang p.s.(炒鋼)(石巖里 9호분 鐵塊)

B. Smelting and steel making at the same are

C. Kiln of charcoal(white charcoal)

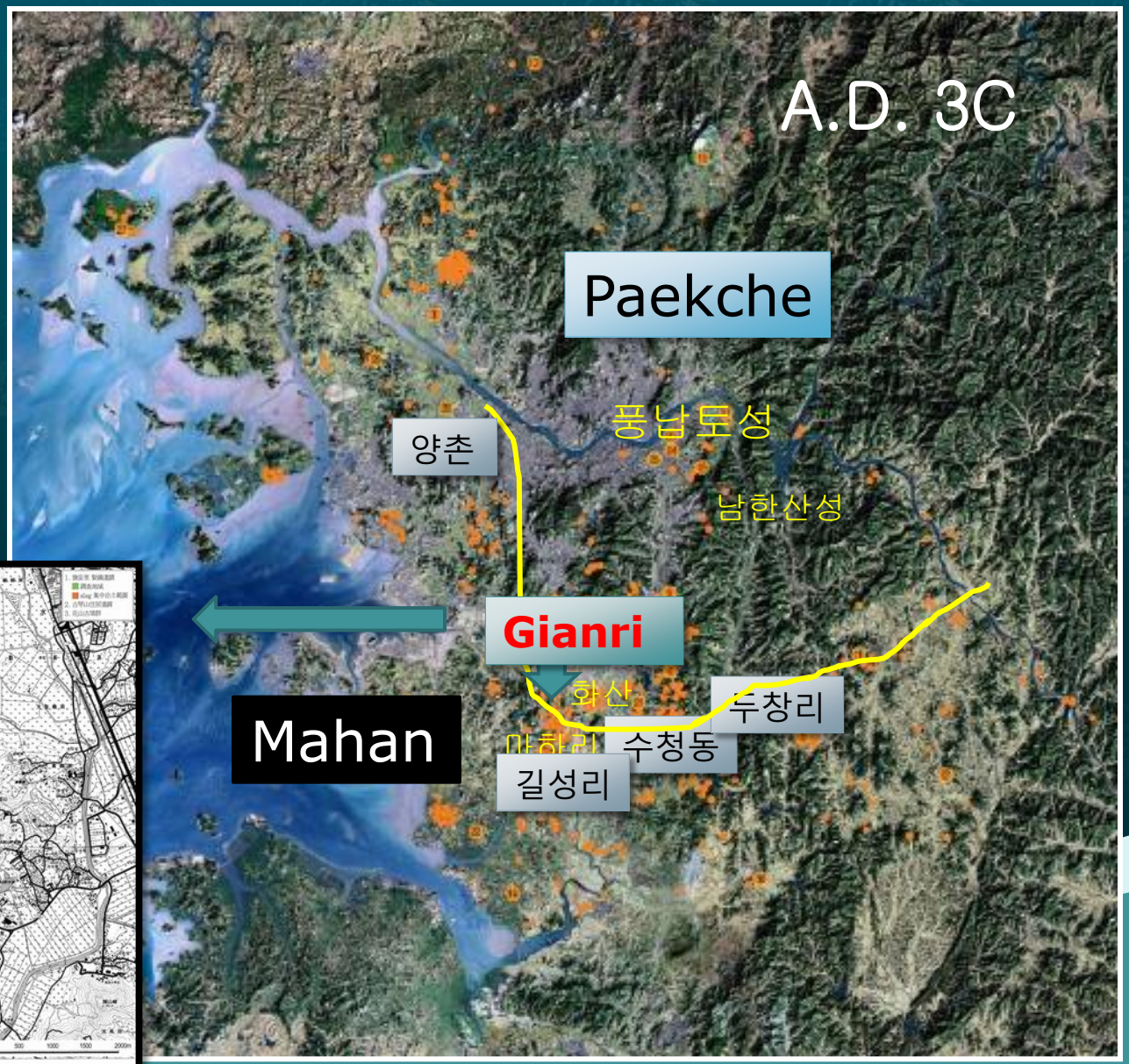
(3) Important meaning

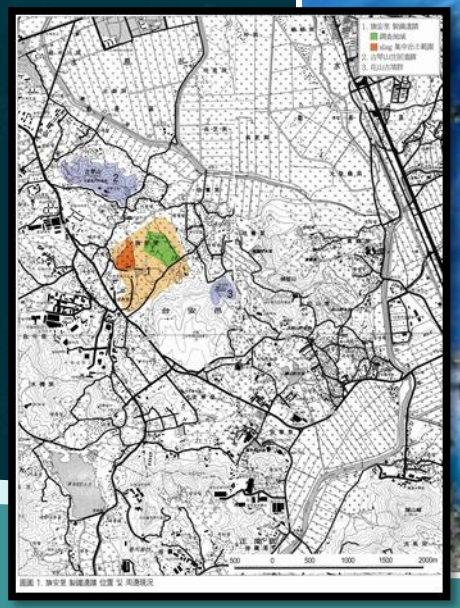
A. Relationship between Paekche and Lo-lang

→ inflow of parched steel technology

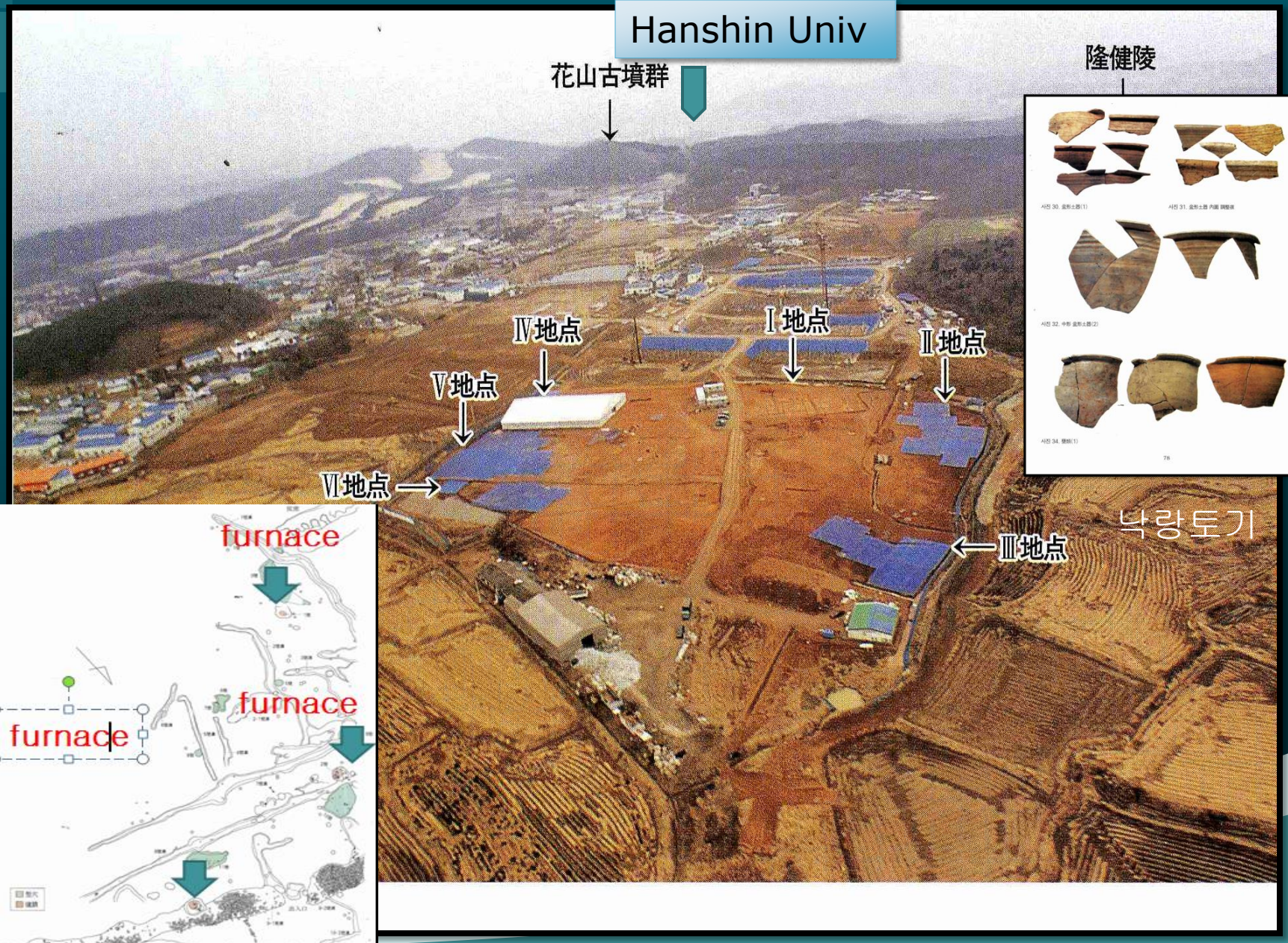
B. Relationship between Mahan and Lo-lang(낙랑)

Paekche and Mahan(A.D.3C)





Hanshin Univ



Excavated point

Ⅲ. Development after 4 century

1. Situation of Miho-river

1) upper area(Seokzangri, Gusanri site)

(1) location : lower hill

(2) type :

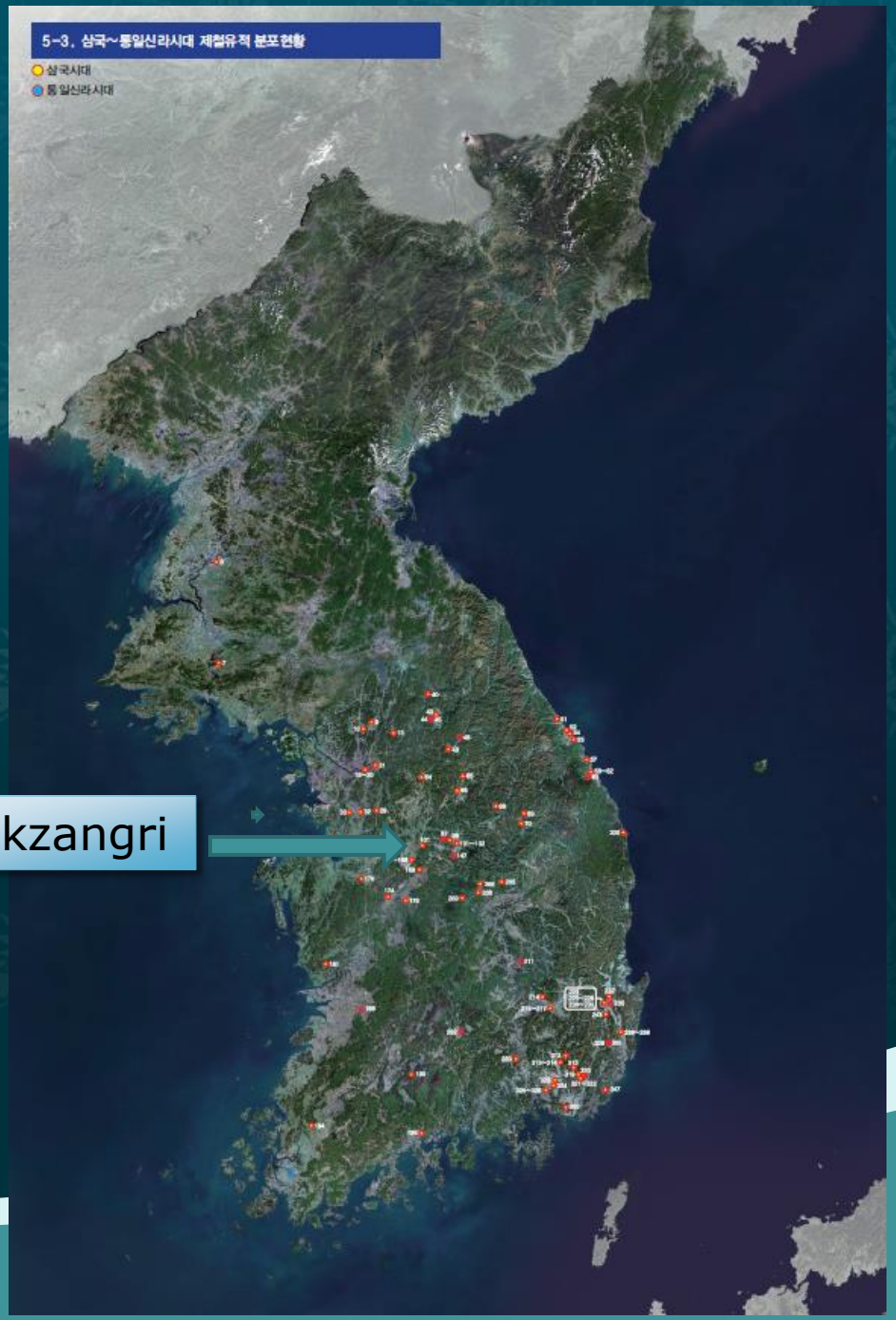
A. smelting : box type? and shaft

B. steelmaking : box type furnace(ore powder)

C. casting : inner moulds only * no furnace

D. hammering : small furnace(scale)

Iron making site from three kingdom era to united shilla



1. Meaning of Seokzangri site
→ consistent total iron making place

1) 7 iron making place of on the lower hills(area of 1400m×700m)

2) smelting→steelmaking→hammering and casting(standard site of ancient iron making)

- Large scale and consistent process
- → concentration of distribution,
- → specialization of technology,
- → increase of productivity

3) Efficent control of production and distribution

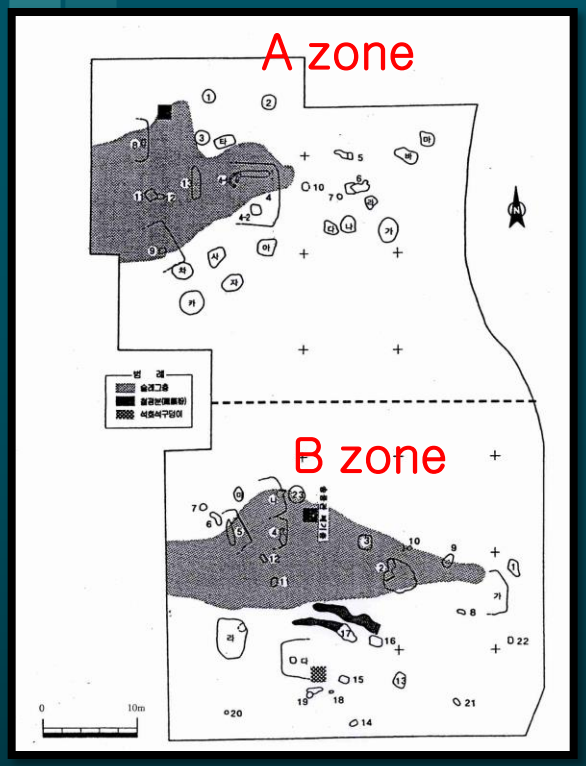
* epoch-making development

4) Producing at country → tributary payment to central place

(to capital ity)

진천 석 장리
제철유적 유구 배치도

arrangement of relics



2. Aspect at middle range of Kin(錦) river basin

(1) Younjeri(蓮提里) site(A.D. 4C)

A. flowed slag(ore not found, didn't use iron sand)
   → half or almost deoxidized raw material

B. possibility : from pig iron → parched steel(炒鋼) ?

C. very large size pit house near the furnace

D. charcoal kiln //

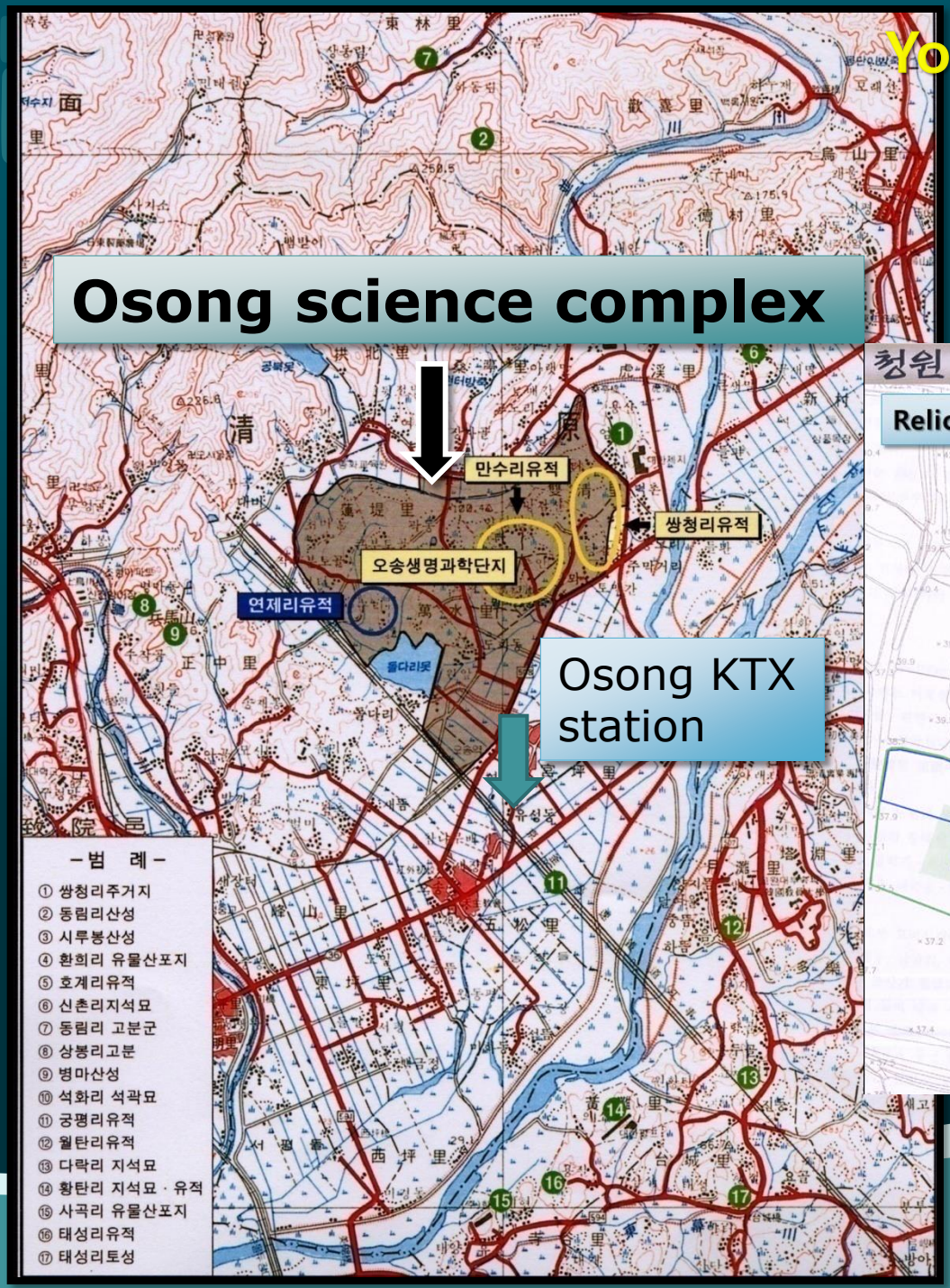
* <important meaning>

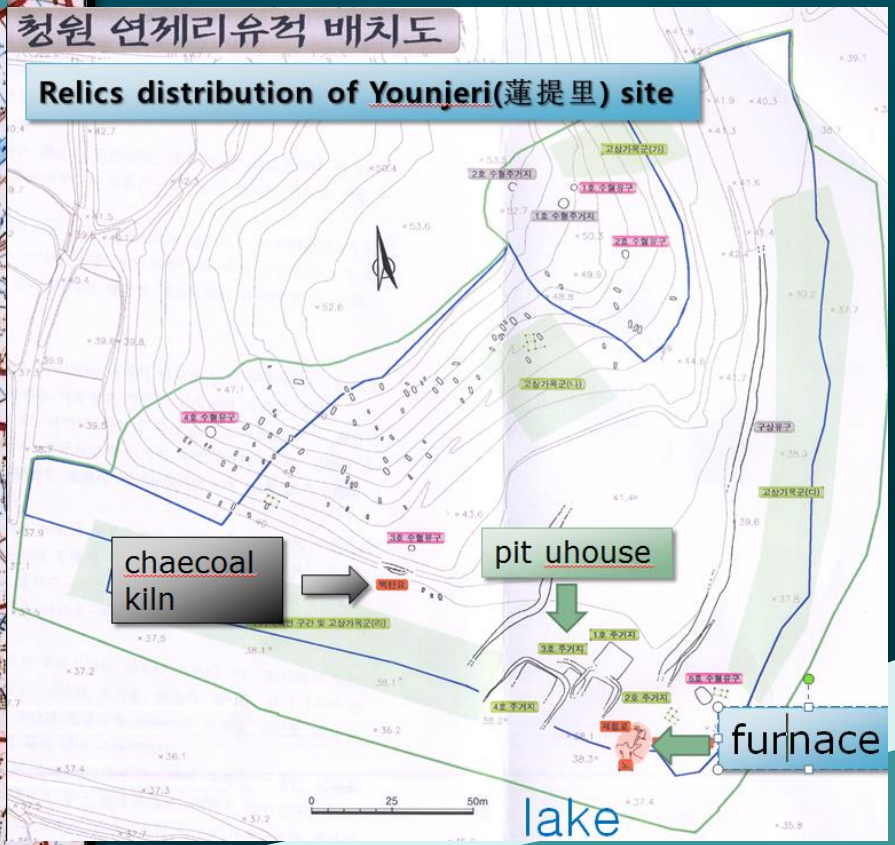
Working site of the second process(not smelting)

→ We can understand the producing and the distributing system of iron making

Younjeri(蓮提里) site

Osong science complex





3. Aspects of Chungju(忠州) area (middle range of south Han river)

1) Chilgumdong(漆琴洞) site(A.D. 4C)

A. location : near the Han river(merit of transportation)

B. near places : 70 iron making sites of medieval time

C. only 1 furnace excavated → 1.8m diameter

D. underground structure to protect moisture

E. surroundings : distributed area of many slags

F. north part of 200m : earthen castle(彈琴臺)

* Relationships between center and periphery

- (rulling system by the distributary payment)

3. Lower Han river
Pungnap capital castle(風納土城)

A. no smelting site→ smithing and casting(blastpipe, moulds of hoe)

B. manual industry in capital castle

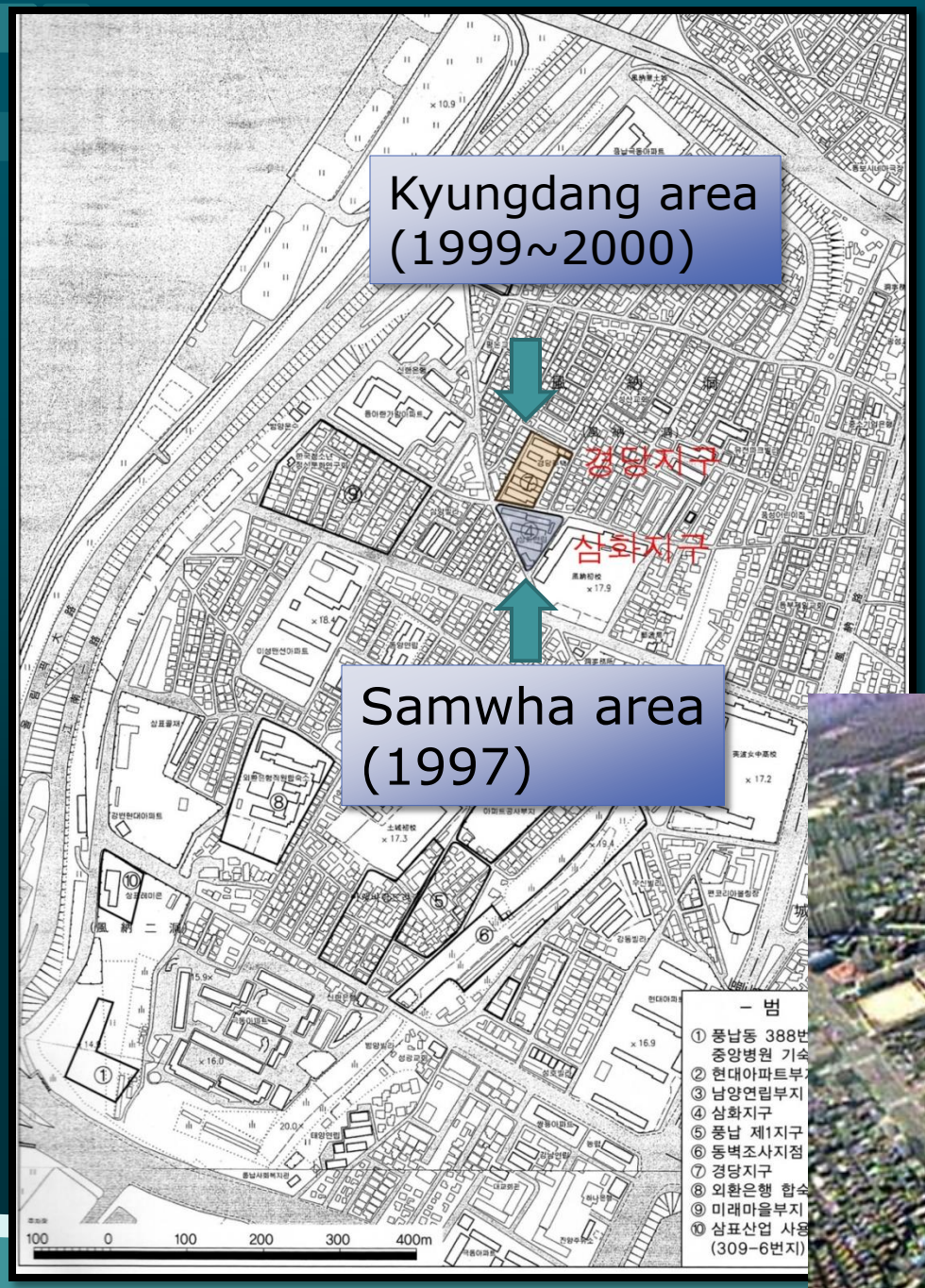
→ 官營手工業 (centralization of iron making by national control)

→ manual industry of royal palace

→ enlarging the finance and the national prosperity

* iron making and distribution system of civillian level

* sponge iron from iron sand (Whaseong Banwoldong)



풍납토성 조사지점

Pungnap capital castle
(風納土城)

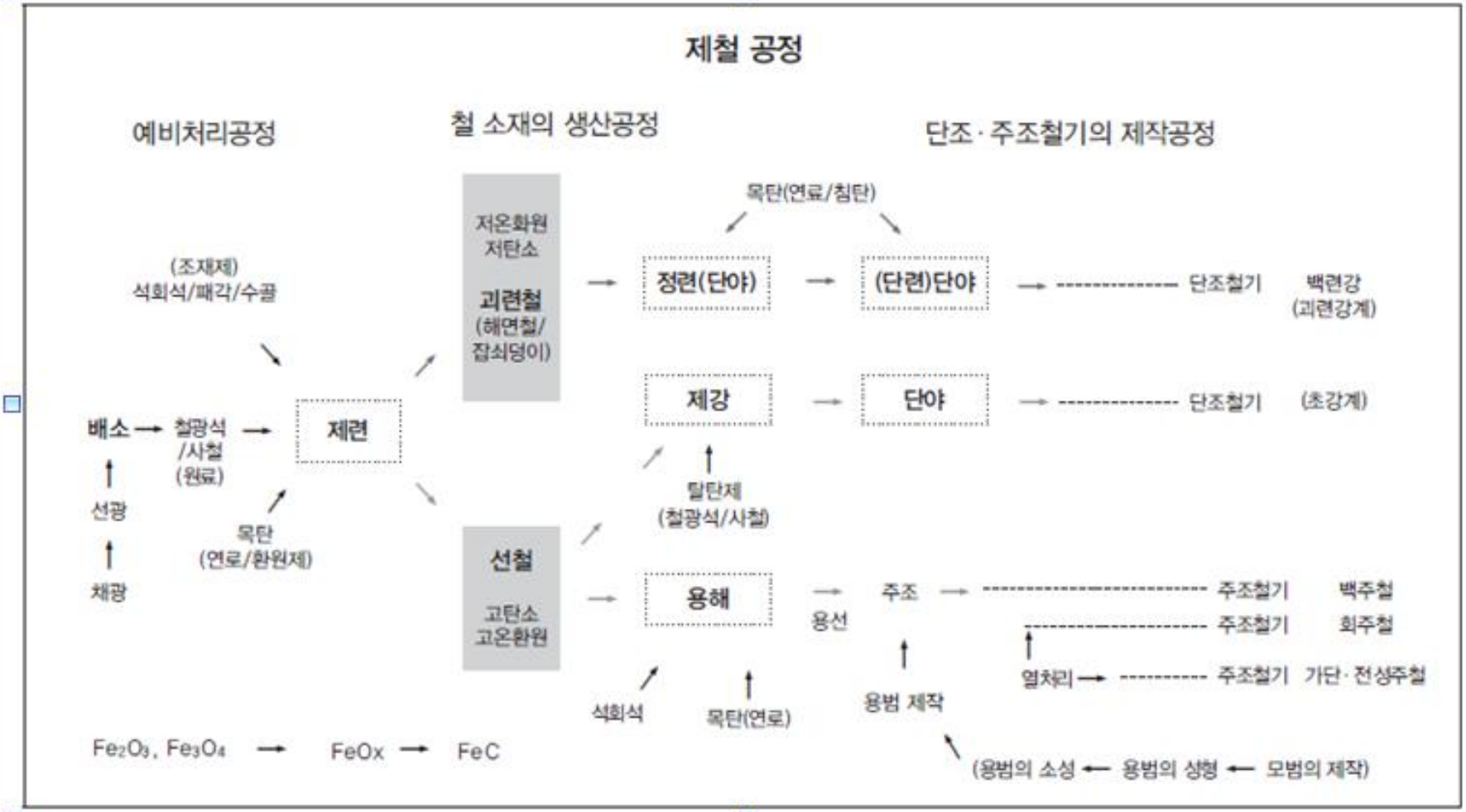


그림 13. 우리나라 전근대 제철의 공정체계도(한국문화재조사연구기관협회 2012)

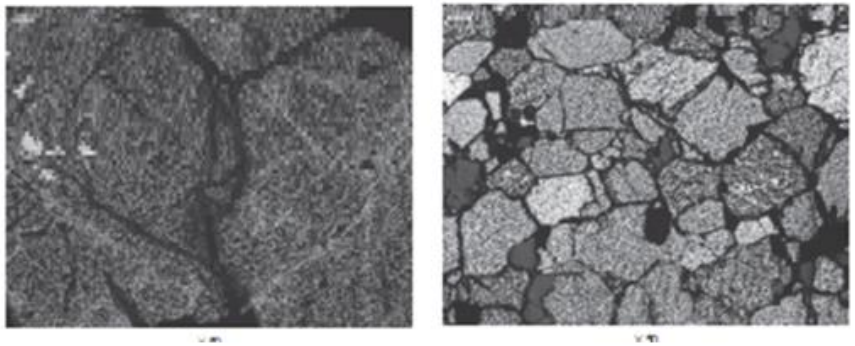
The kinds of iron making products

〈표 3〉 분석된 생산품의 종류와 특성

생산공정	생산품	생산법	특성
	sponge iron	고체환원법에 의해 형성.	다공질, 맥석성분 다량함유, 탄소함량 낮음.
smelting	선철과 + pig iron	고온액체환원법에 의해 철광석이 용융을 거쳐 환원이 완료된 상태.	Fe-C의 상태.
	환원	철광석이 환원된 단계.	철광석의 환원이 완료되어 괴련철이나 Fe-C의 단계에 있지만, 괴련철괴인지 선철괴인지 확인되지 않은 상태.
	반환원괴	철광석이 환원되는 중간 단계.	FeOx의 상태. 산화철인 Wüstite조직과 광물상인 Fayalite조직이 혼재. 노 내 분위기에 따라 탄소 함유조직도 존재.
refining	Parched(decarburized) steel 괴련강	괴련철을 반복 단련하여 불순물로 산화물을 제거한 강괴.	Ferrite와 Pearlite로 구성된 아공석조직. 조직과 탄소량이 균일하지 못함. 비금속개재물은 크고 많으며, Wüstite(FeOx)조직이 있음.
smithing	steel from sponge iron	반복단련한 강괴.	Ferrite와 Pearlite로 구성된 공석강조직. 조직 내 탄소 함량이 균일함. 비금속개재물은 미세하고 균일하게 분포하고 성분에 칼슘(CaO)성분이 비교적 많음.
casting	white pig-	선철을 용해한 다음 용범에 투입하여 주조철 제작.	공정조직인 Ledeburite조직으로 구성. 열처리하여 회주철을 만듦.

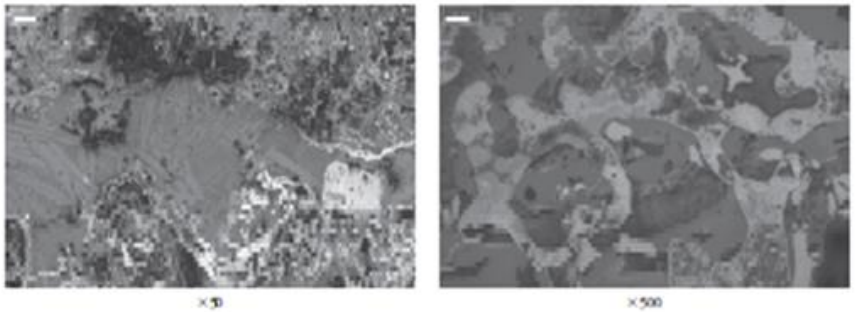
각 공정의 금속조직

Pre-treated ore by fire



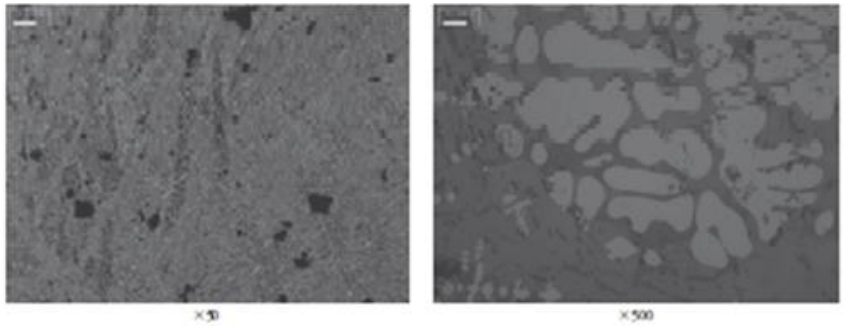
배소된 철광석 금속조직

Deoxidized metal structure



환원괴의 금속조직

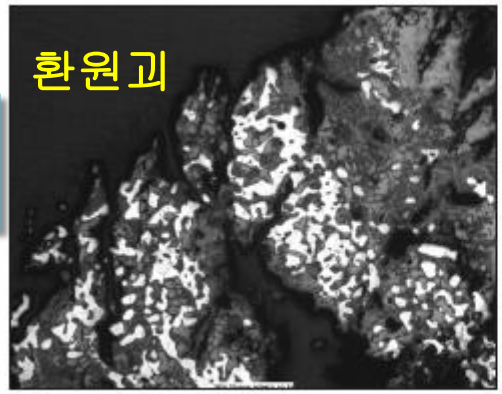
Half oxidized metal structure



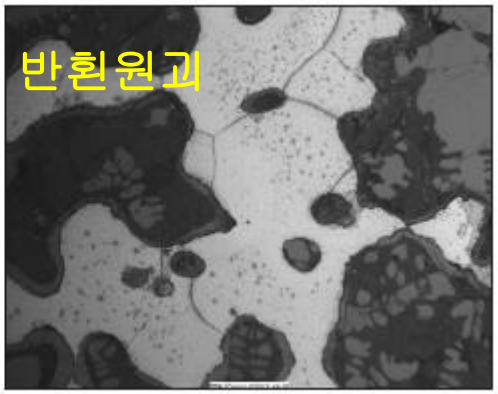
반환원괴 금속조직

그림 12. 충주 칠금동 제철유적 자료의 금속학적 분석결과

deoxidized
raw material



① 반환원괴의 미세조직(×50)



② 반환원괴의 미세조직(×500)

half dexoidized
raw matarial

sponge iron
괴련강

raw mterial of parched steel
초강


사진 6. 철기 편 인부 전체조직

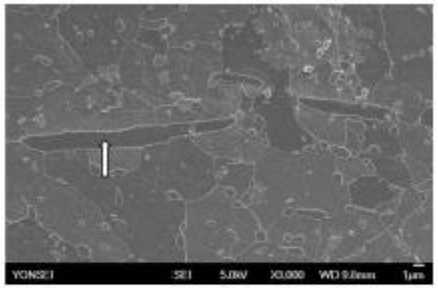


사진 9. 비금속개재물 SEM과 분석위치

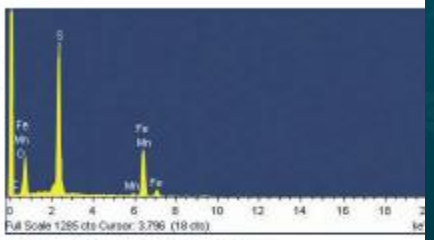
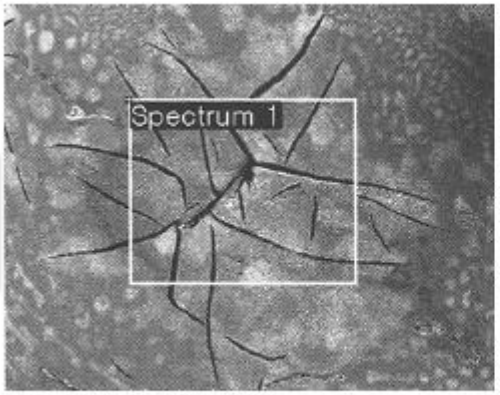


그림 1. 분석지점 EDS spectrum

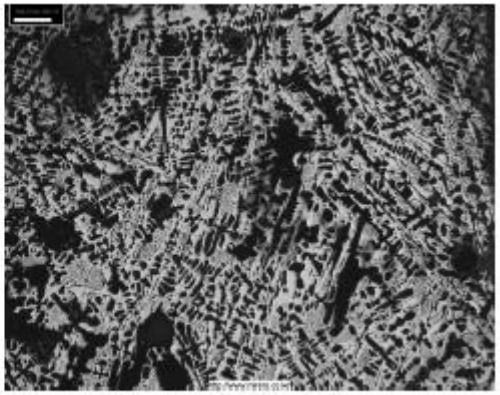
표 2. 〈사진 9〉의 표시부분 EDS 분석결과 (in weight %)

분석위치 \ 성분	C	O	S	Mn	Fe	Total
분석지점	7.12	3.22	33.53	3.37	52.77	100.01

grey pig iron
Of hoe



① 주조펑이의 인부조직(용인 수지유적)

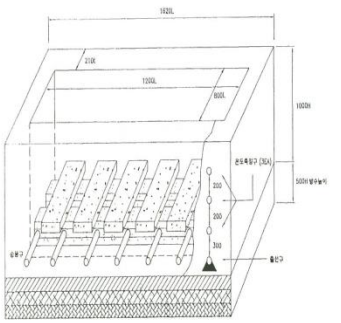

② 철제 보습의 인부조직(x50, 오산 내삼미동 유적)

〈그림 3〉 주조펑이 인부와 보습의 인부조직

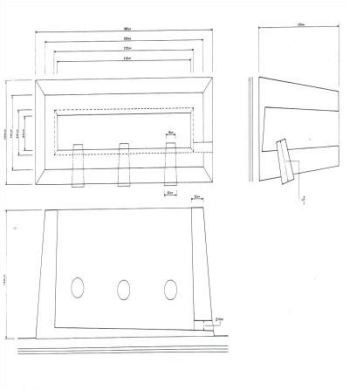
대성리 철부
인부조직

Daeseongri

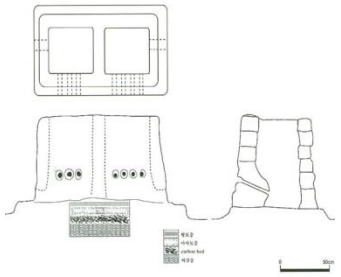
철제련 실험로 각종



한국과학기술원 금속재료연구단(1991)



청주 박물관(1997)



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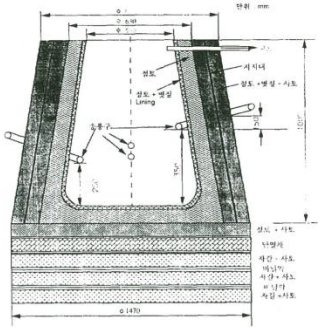

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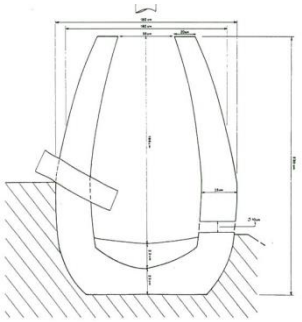

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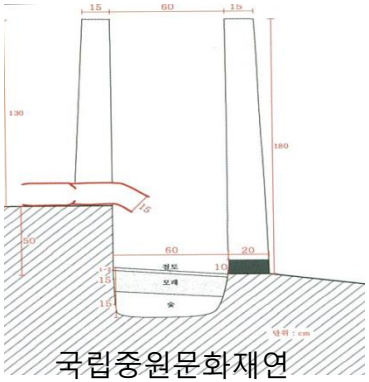
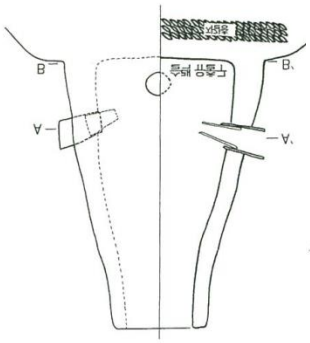
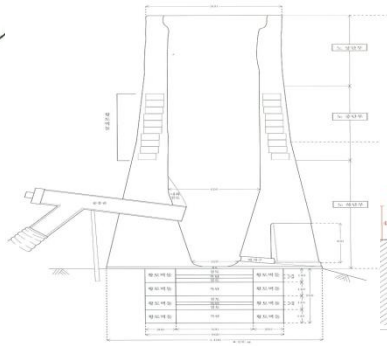


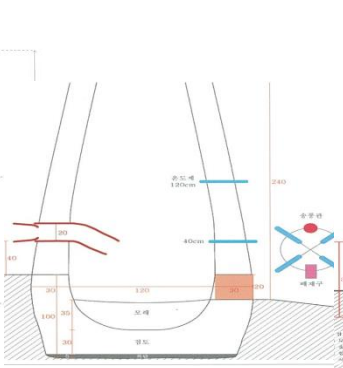
국립중원문화재연구소(2015. 7. 28)



세연 철박물관(2003)



중원문화재연구원(2014)



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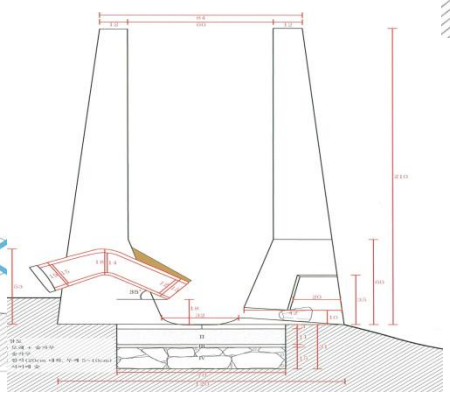

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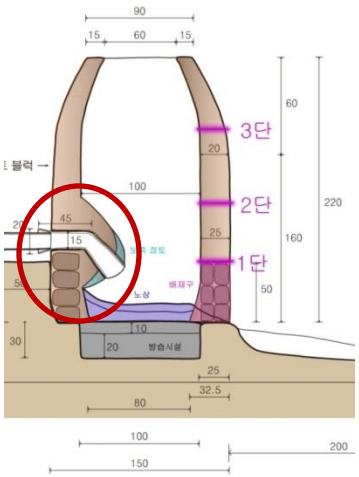

한국연구재단팀(2016)

적색: 상형로, 흑색 : 원통형로

Ⅴ. *closing remarks*

1.Began from low level technology

2. Development of high level iron making technology

2. Introduced parched steel technology A.D.3C

→ rapid developmemt of steel weapons

3. Centralization and enlargement of iron making place from A.D. 4century

4. Systematization of iron making process

5. Regional devision of labor and systematic distribution

6. Controlled by nation

→ distributary payment to central place

7. Partly produced sponge iron from iron sand

※ totally estimated as the most developed level in the world

Thank you