

GEOCHIMICA ED ARCHEOLOGIA

Lezione 2

Gianluca Sottili

AA 2022-23

Riepilogo della prima lezione

Definizione: la cronostratigrafia isotopica

Teoria: introduzione alla nomenclatura e all'uso degli isotopi

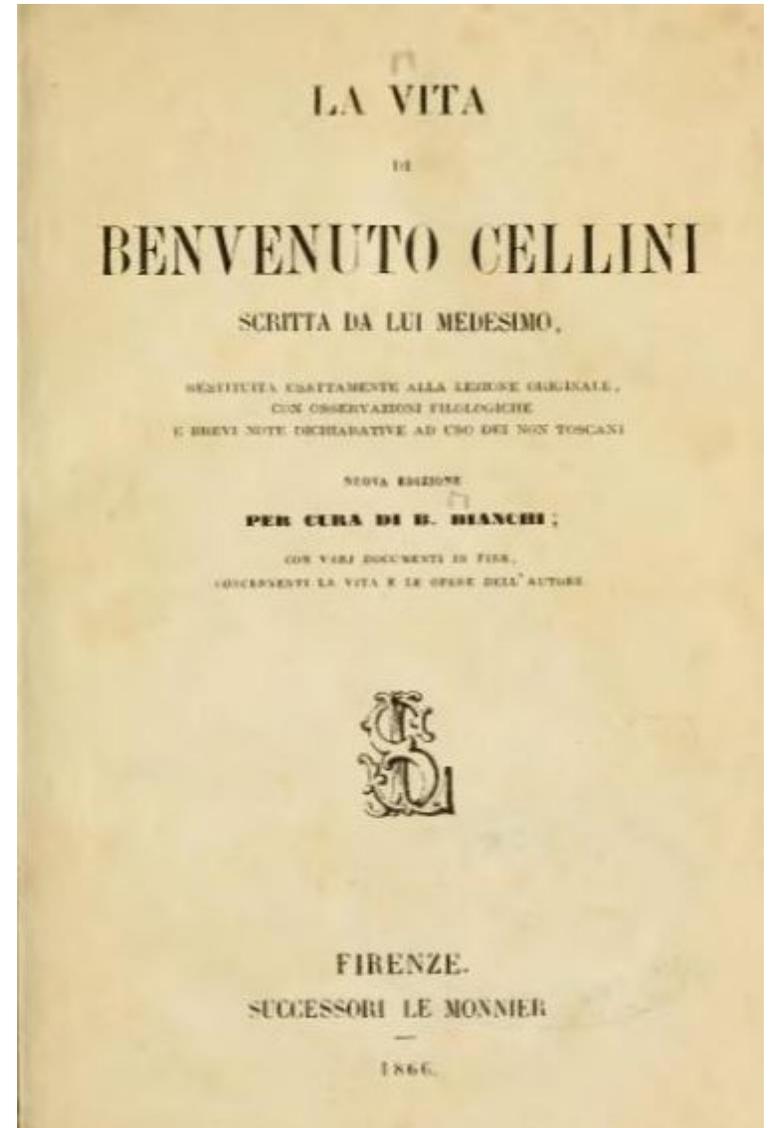
Applicazioni della geochimica isotopica all'archeometallurgia

La teoria della 'pre-colonizzazione' fenicia.

Le fasi dell'espansione fenicia nel Mediterraneo occidentale e la cronologia dell'apertura delle rotte commerciali dell'argento verso Occidente.



"Perché Lisippo ti modellò così abbattuto e mescolò al bronzo l'afflizione?" (Gemino)





“Tutta la palpebra intorno e le ciglia gli arse la vampa della pupilla bruciata: crepitavano nel fuoco le radici, come quando un fabbro grande scure o ascia in acqua fredda immerge per temprarla e quella manda fuori un grande sibilo: questa è appunto la forza del ferro; così strideva l’occhio del mostro intorno al palo d’ulivo.” (Odissea IX, vv.371-394)

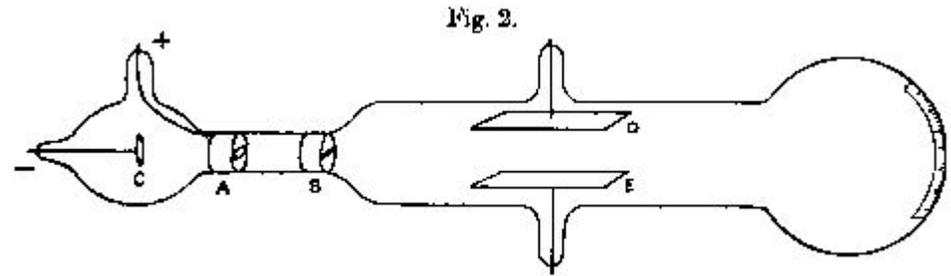


“Se potessimo suddividere un pezzo di ferro in due parti, poi in due parti ancora e così via fino a ottenere porzioni impalpabili di materia, ci accorgeremmo a un dato punto di non poter procedere oltre. Arriveremmo fatalmente a un limite, rappresentato dall'unità-ferro che non si potrà mai suddividere ancora, perché ogni tipo di sostanza è necessariamente costituita dalla somma delle sue unità elementari.”

Democrito, V sec. a.C.



Joseph John Thomson
Premio Nobel per la fisica 1906

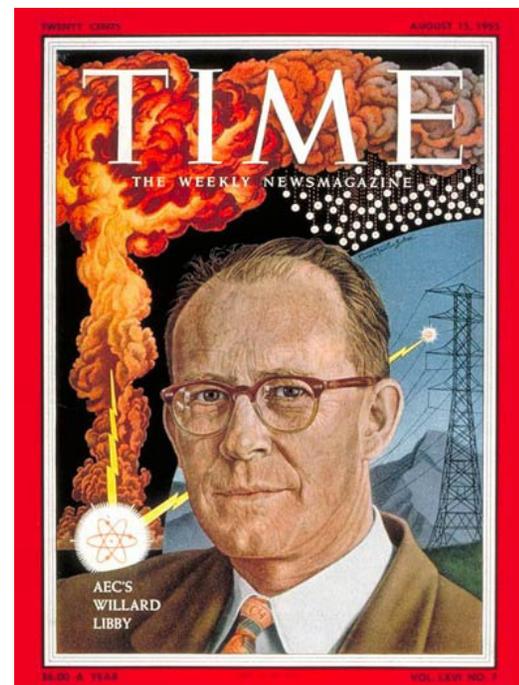


Dallo studio dei raggi catodici Thomson comprese che l'elettrone è una particella subatomica, la prima ad essere scoperta.

Nel 1912 realizzò il primo spettrometro di massa, lo strumento che consentiva di determinare il rapporto tra la massa e la carica degli ioni.

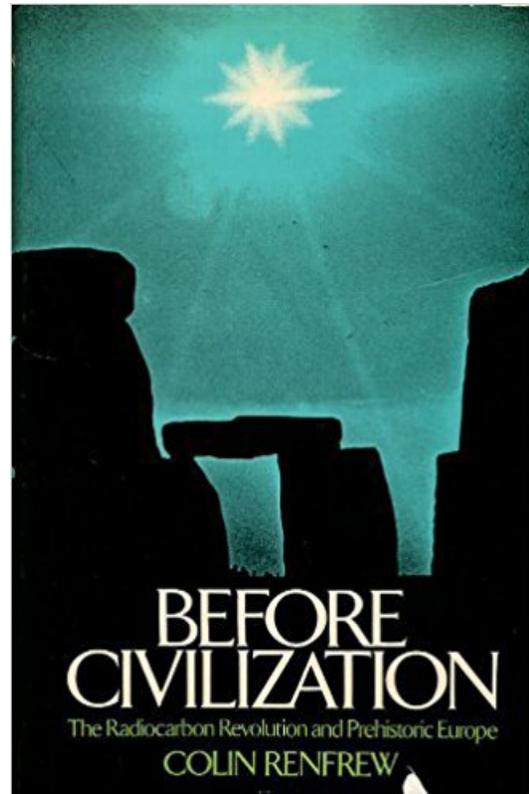
La geochimica isotopica e la “rivoluzione del radiocarbonio”

Nel 1949 un gruppo di scienziati guidati da Willard Libby (premio Nobel per la Chimica nel 1960) sviluppo la tecnica per le datazioni radiometriche.



Le datazioni radiocarbonio hanno rivoluzionato lo studio della preistoria.

Prima che divenisse una tecnica accessibile, le datazioni erano basate fondamentalmente su due tecniche: i cambi nella forma dei manufatti nel tempo e, occasionalmente, la presenza di manufatti in contesti cronologicamente noti (ad es. il rinvenimento delle ceramiche micenee in Egitto, in contesti datati grazie a delle iscrizioni).



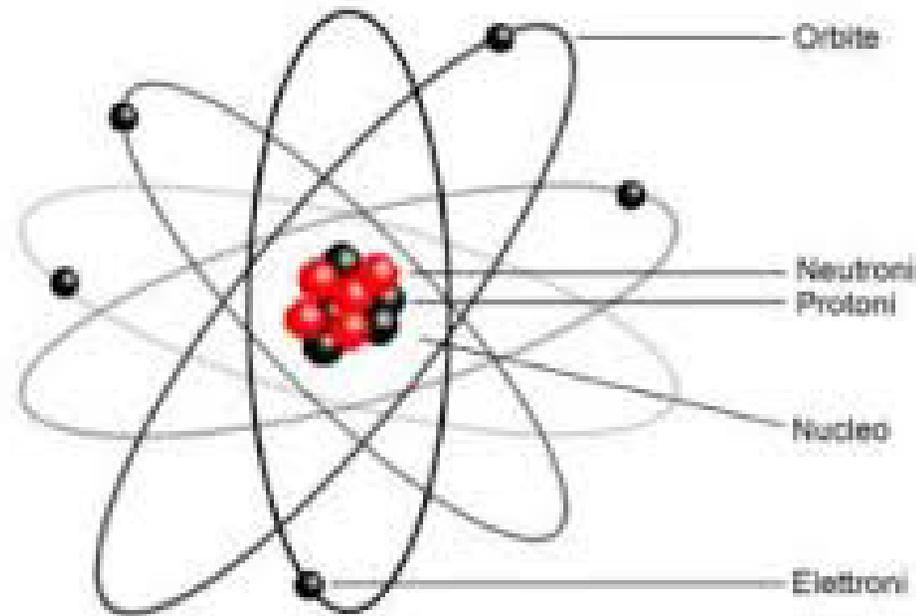
1 Introduction

The study of prehistory today is in a state of crisis. Archaeologists all over the world have realized that much of prehistory, as written in the existing textbooks, is inadequate: some of it quite simply wrong. A

La teoria diffusionista collassò e gli archeologi iniziarono a mettere a fuoco una nuova visione in cui le singole società potessero sviluppare al proprio interno processi di cambiamento e di innovazione tecnologica e sociale (funzionalismo).



Il modello atomico di Rutherford (1911)



i **protoni** (carichi positivamente) e i **neutroni** (privi di carica) formano il "nucleo" (carico positivamente); protoni e neutroni sono detti quindi "nucleoni";

- gli **elettroni** (carichi negativamente) sono presenti nello stesso numero dei protoni e ruotano attorno al nucleo senza seguire un'orbita precisa (l'elettrone si dice quindi "delocalizzato"), rimanendo confinati all'interno degli **orbitali** (o "livelli energetici").

METALLI

- sono **SOLIDI** a temperatura ambiente
- hanno un **aspetto LUCENTE** (tranne il mercurio),
- sono buoni **CONDUTTORI** di calore ed elettricità,
- sono **DUTTILI** e **MALLEABILI**.

I metalli sono numerosi: più di 80 e fra i più importanti ci sono il ferro, l'alluminio, il rame, l'oro, l'argento, il piombo.

NON METALLI

- non sono buoni **CONDUTTORI** di calore ed elettricità,
- non sono **DUTTILI** e **MALLEABILI**
- possono essere **SOLIDI, LIQUIDI** o **GASSOSI**

SEMIMETALLI

sono in parte **metalli** e in parte **non metalli**; sono anche detti **SEMICONDUTTORI**.

- sono buoni **CONDUTTORI** di **ELETTRICITA'** (caratteristica dei metalli)
- **ISOLANTI** (caratteristica dei non metalli)

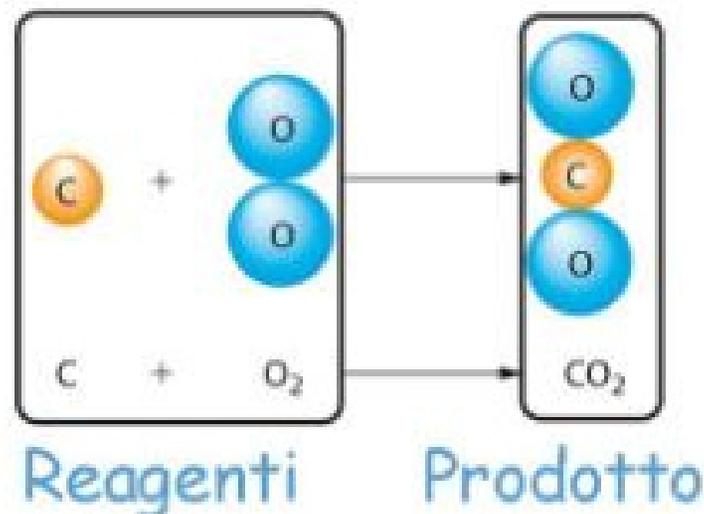
Esempi di semimetalli sono l'arsenico e il silicio.

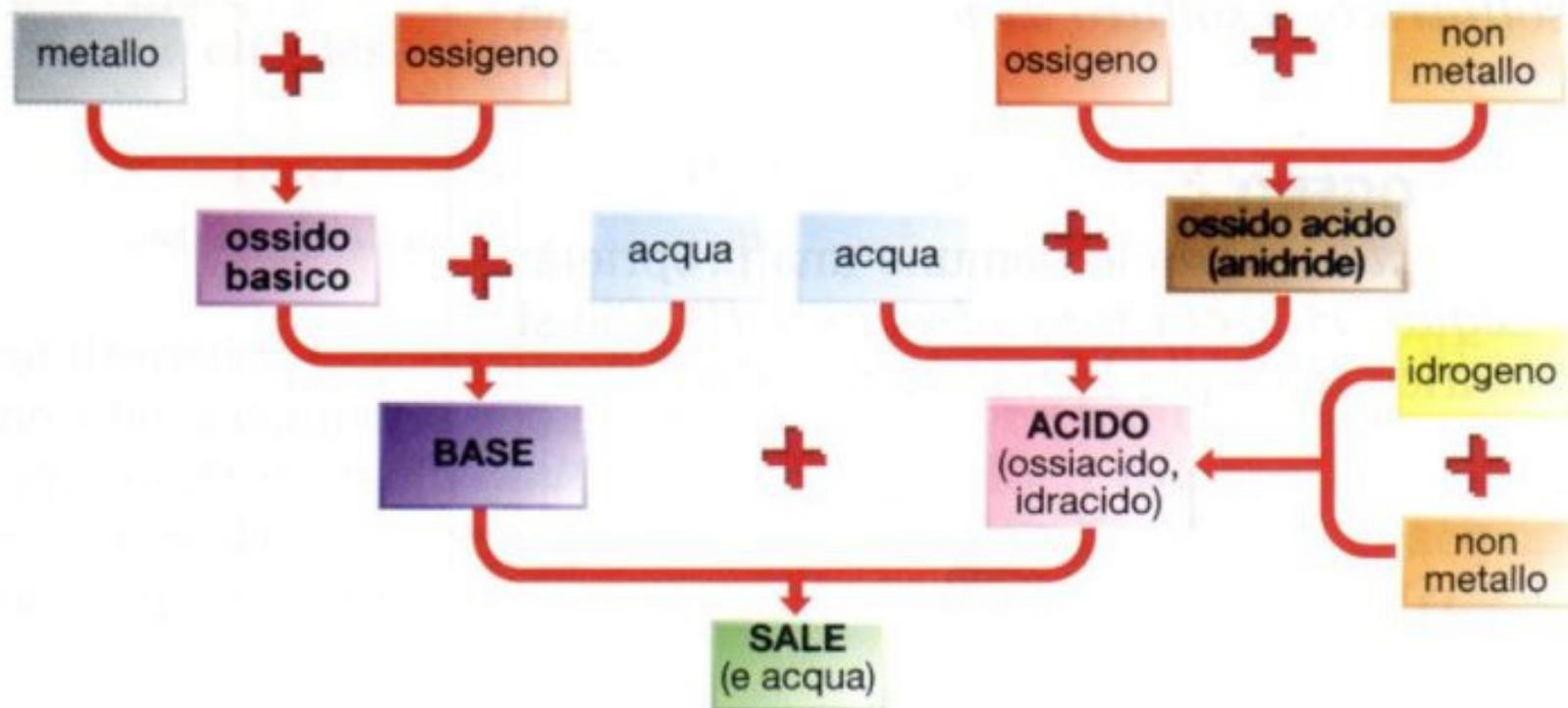
GAS NOBILI

sono poco presenti nell'atmosfera e sono **INERTI**, cioè non reagiscono a contatto con altri elementi.

Le Reazioni Chimiche

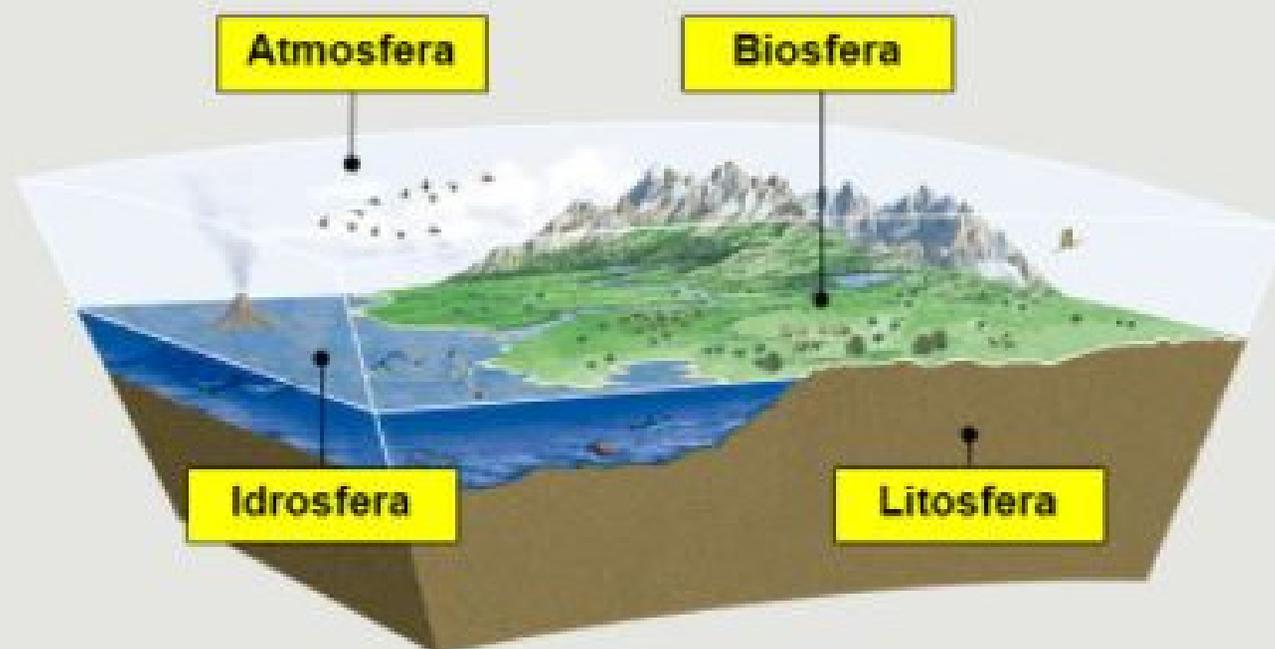
Una **reazione chimica** è un processo in cui partendo da alcune sostanze (**reagenti**) si ottengono sostanze diverse (**prodotti**).

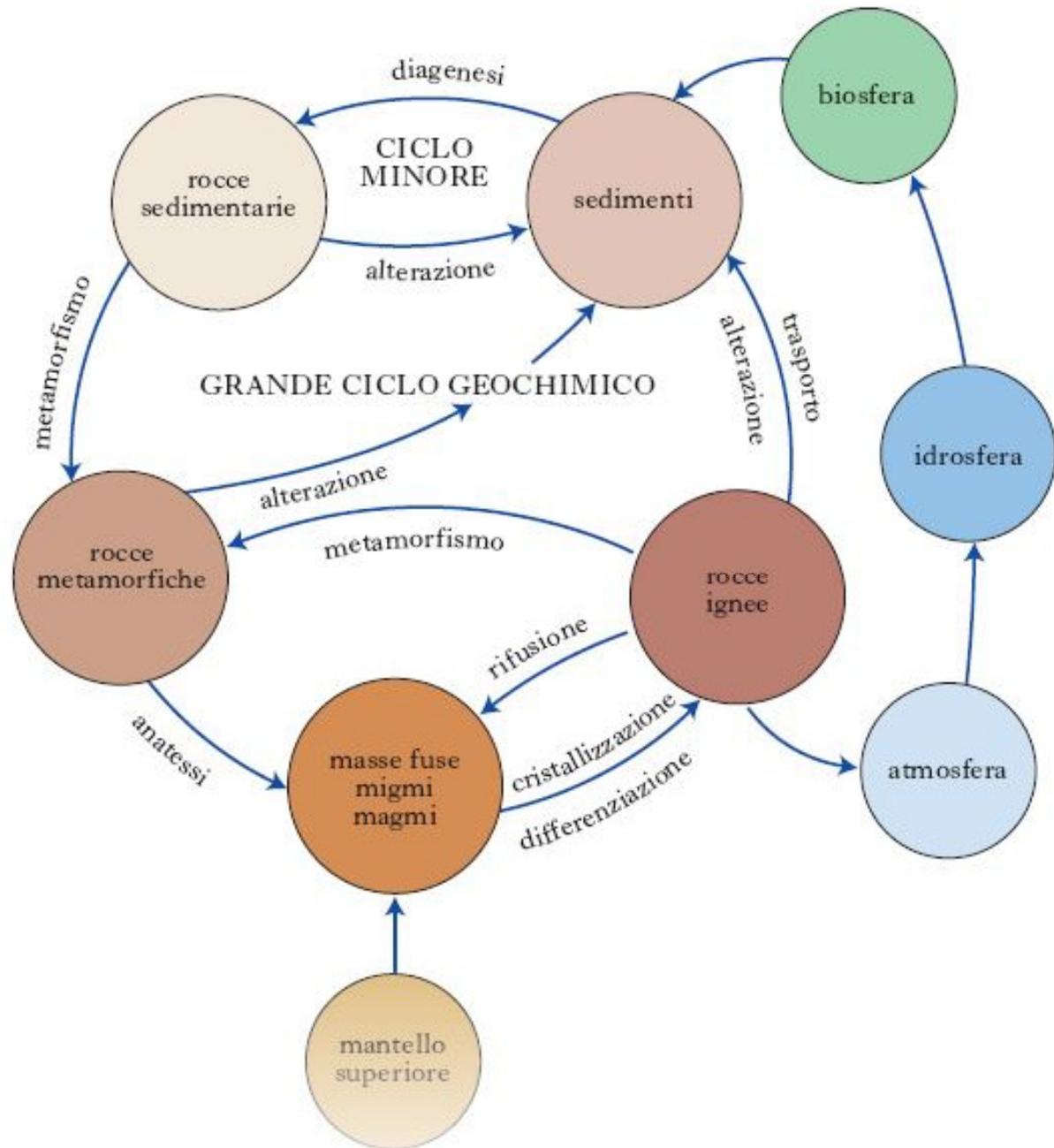




L'insieme delle diverse parti del nostro pianeta e le loro reciproche interazioni costituiscono il **sistema Terra**.

La Terra può essere idealmente suddivisa in «**sfere**», in base alla densità dei materiali che la costituiscono.





Minerali

- **Minerali** sono solidi naturali con un elevato ordinamento a scala atomica ed una definita (ma non fissa) composizione chimica.

Rocce

- **Rocce** sono aggregati naturali di minerali legati tra loro da forze di coesione a carattere permanente e formati tramite uno o più processi geologici.

Ambiente di formazione di diverso tipo:
magmatico, sedimentario e metamorfico.

MINERALI E ROCCE SONO DUE OGGETTI
BEN DISTINTI TRA LORO!

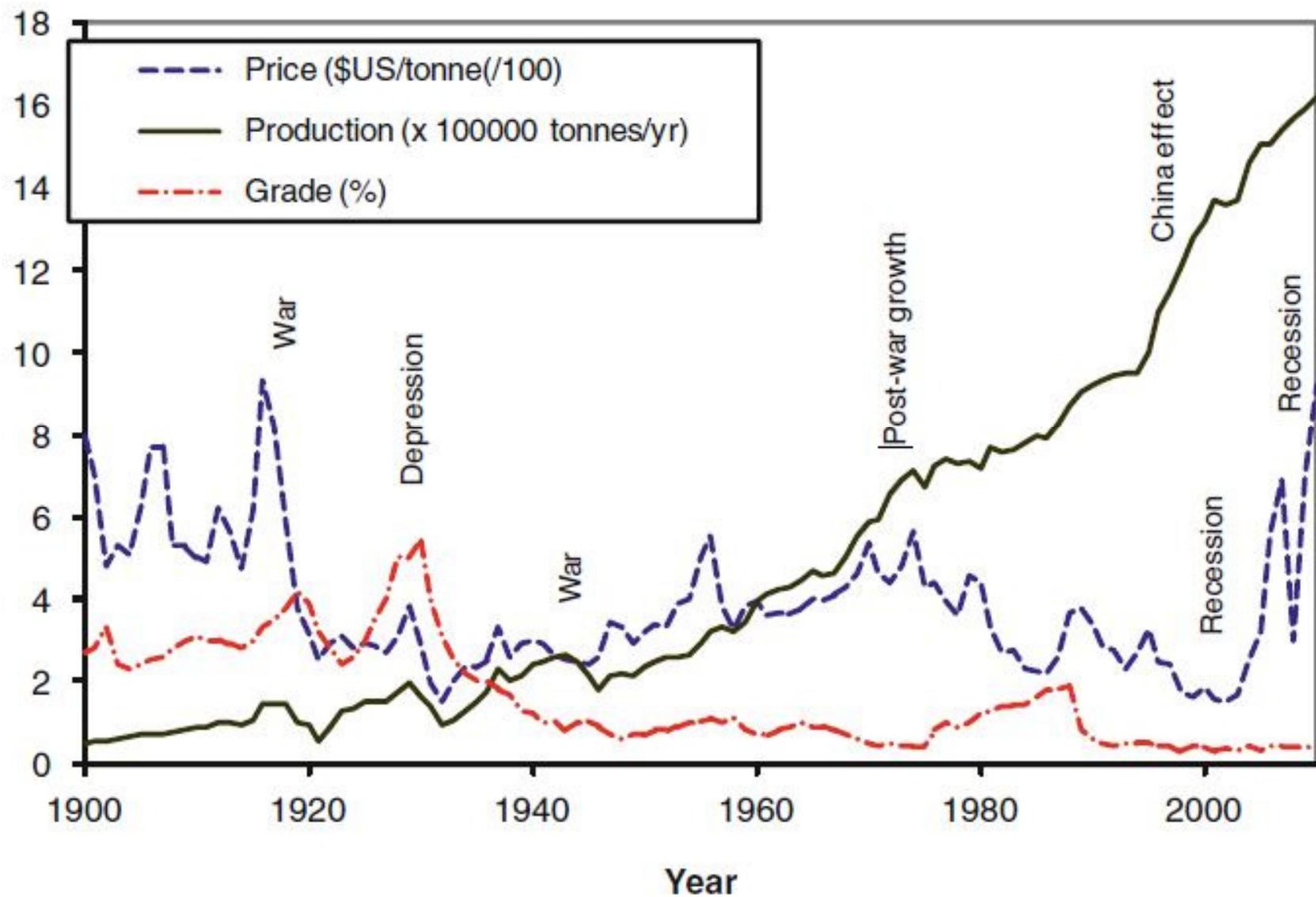


Fig. 1.1 Evolution in the price and production of copper over the past 120 years (statistics from



Minerali di argento



L'argento nel mondo antico

■ A glimpse into the Roman finances of the Second Punic War through silver isotopes

F. Albarède^{1,2*}, J. Blichert-Toft^{1,2}, M. Rivoal¹, P. Telouk¹

1. École Normale Supérieure de Lyon and CNRS, 69007 Lyon, France
- * Corresponding author (email: falbarede@gmail.com; albarede@ens-lyon.fr)
2. Earth Science Department, Rice University, Houston, TX 77025, USA



Quadrigatus Cr 29/3



Denarius Cr 60/1

Figure 1 The pre-reform (pre-211 BC) *quadrigatus* (top) vs. the post-reform *denarius* (bottom). 'Cr' refers to Crawford's nomenclature (Crawford, 1974).

Title

Abstract

Introduction

Material and Methods

Results and Discussion

References

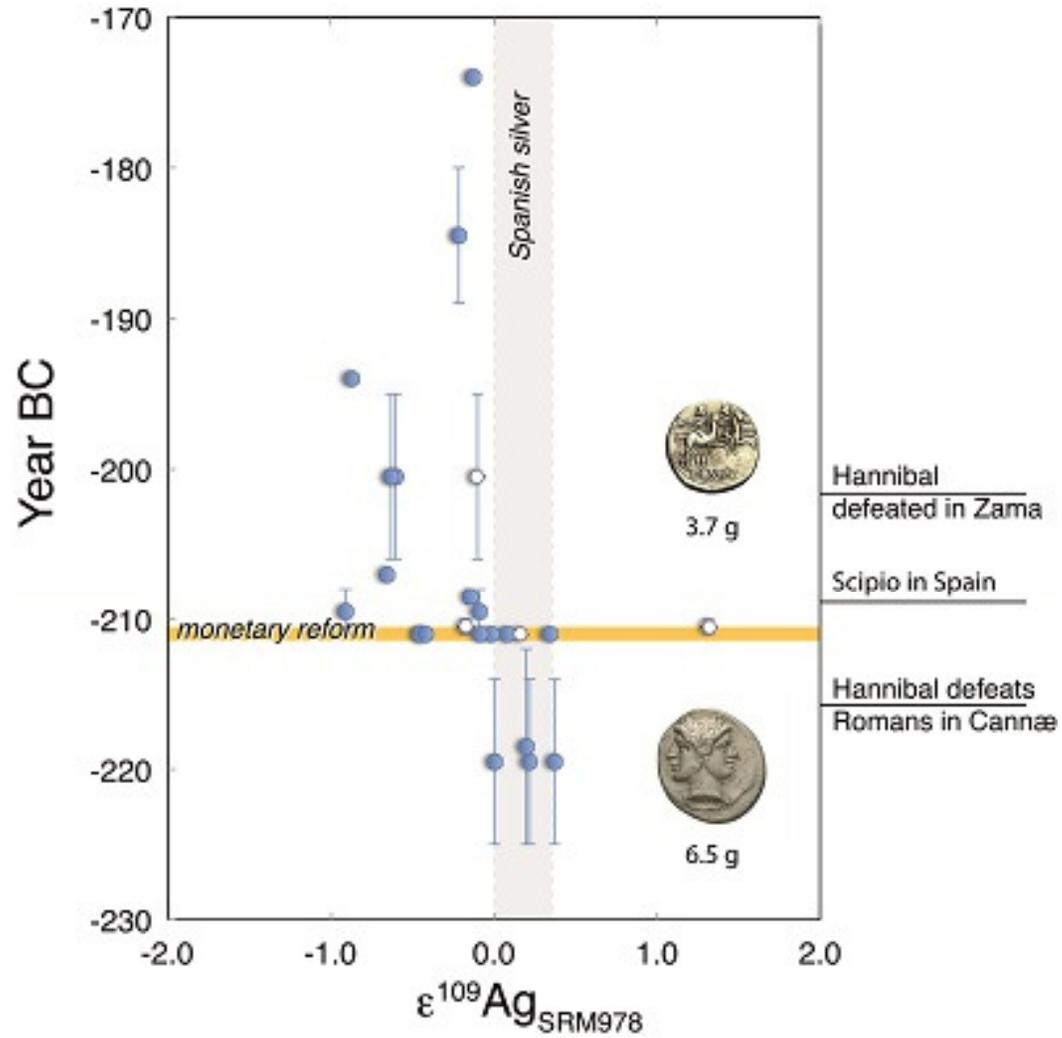
Il tema generale: la riforma monetaria Romana del 211 a.C che rappresentò l'istituzione di un sistema monetario a sostegno dell'espansione militare di Roma nei secoli successivi

Il tema specifico: definire le aree di provenienza dell'argento nelle monete romane prima e dopo la riforma del 211 a.C.

Materiali: analisi isotopica (Ag e Pb) di 24 monete di argento (denarii, quadrigati e vittoriati) risalenti a prima e dopo la riforma del 211 a.C.

Metodi: applicazione di un metodo innovativo “per dissoluzione” di Pb e Ag molto meno distruttivo delle tecniche usate in passato finalizzato alla determinazione del contenuto isotopico $^{109}\text{Ag}/^{107}\text{Ag}$.

Risultati



Albarède et al., 2016 "A glimpse into the Roman finances of the Second Punic War through silver isotopes" *Geochemical Perspectives Letters*

Conclusioni:

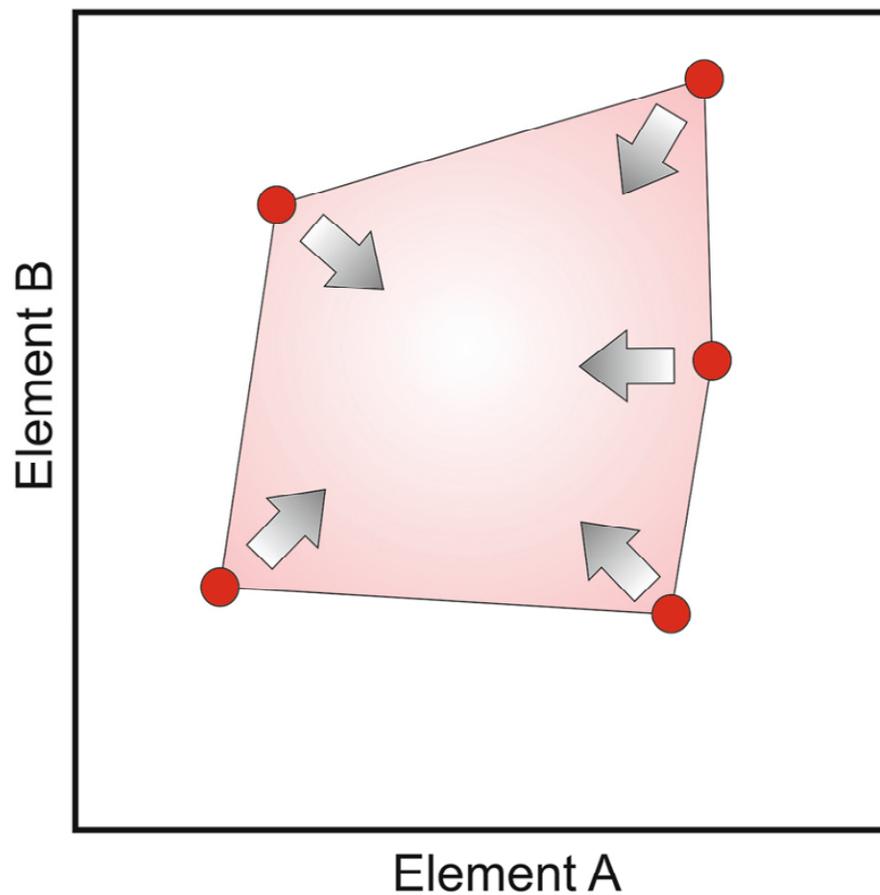
-Le zone di approvvigionamento dell'argento prima e dopo la riforma del 211 a.C. cambiano drasticamente: la Spagna cessa di essere la zona di estrazione dell'argento e le monete coniate sono più piccole, anche se mantengono un elevato grado di purezza dell'argento.

-Implicazioni:

La riforma monetaria del 211 a.C. è stata effettuata in brevissimo tempo e coincide con la cessazione dell'arrivo dell'argento dalla Spagna (invasione di Annibale dell'Italia) e con l'arrivo (insufficiente) di argento da altre fonti (saccheggio di Capua e Siracusa?).

Il fatto di ridurre le dimensioni delle monete, pur mantenendo alto il grado di purezza del metallo, indica una duplice volontà del Senato Romano: assicurare la popolazione in un periodo di economia di guerra e di evitare effetti inflazionistici dovuti alla circolazione di nuovo argento.

Il problema del riutilizzo e della rifusione di oggetti e materiali metallici di origine eterogenea



● = siti di provenienza noti

da Radivojević et al., 2018

LA CRONOSTRATIGRAFIA ISOTOPICA

La **cronostratigrafia**

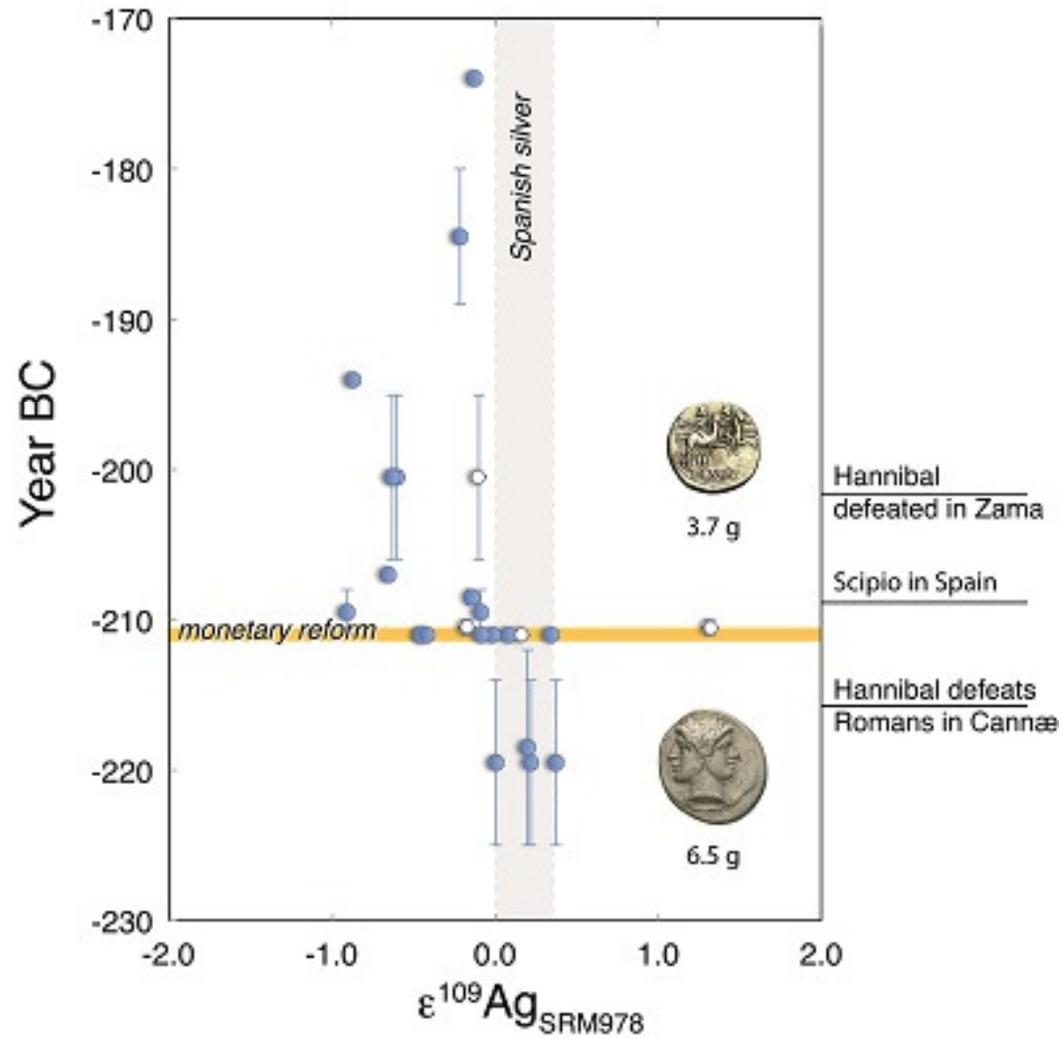
Branca della stratigrafia che studia l'età degli strati e le loro relazioni temporali.

La **cronostratigrafia** è basata in gran parte sull'uso degli **isotopi** e sulla **geocronologia**

La **datazione assoluta** è il processo di determinazione dell'età cronologica di elementi presenti nei sedimenti o di un reperto

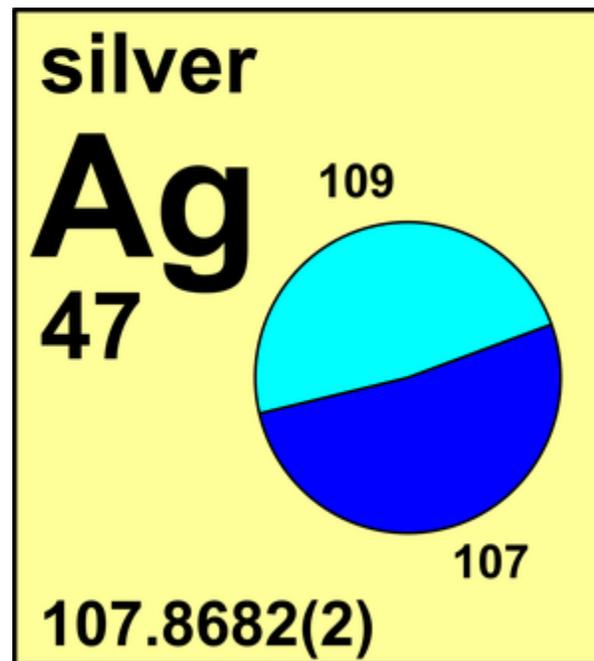
La **datazione relativa** è la determinazione dell'ordine relativo di svolgimento di alcuni eventi avvenuti nel passato, senza necessariamente determinare la loro età assoluta

LA CRONOSTRATIGRAFIA ISOTOPICA



ISOTOPI

Atomi che hanno numero atomico uguale e occupano perciò lo stesso posto nel sistema periodico degli elementi, ma hanno massa atomica diversa.



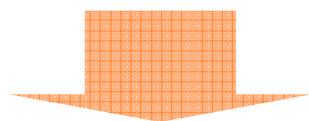
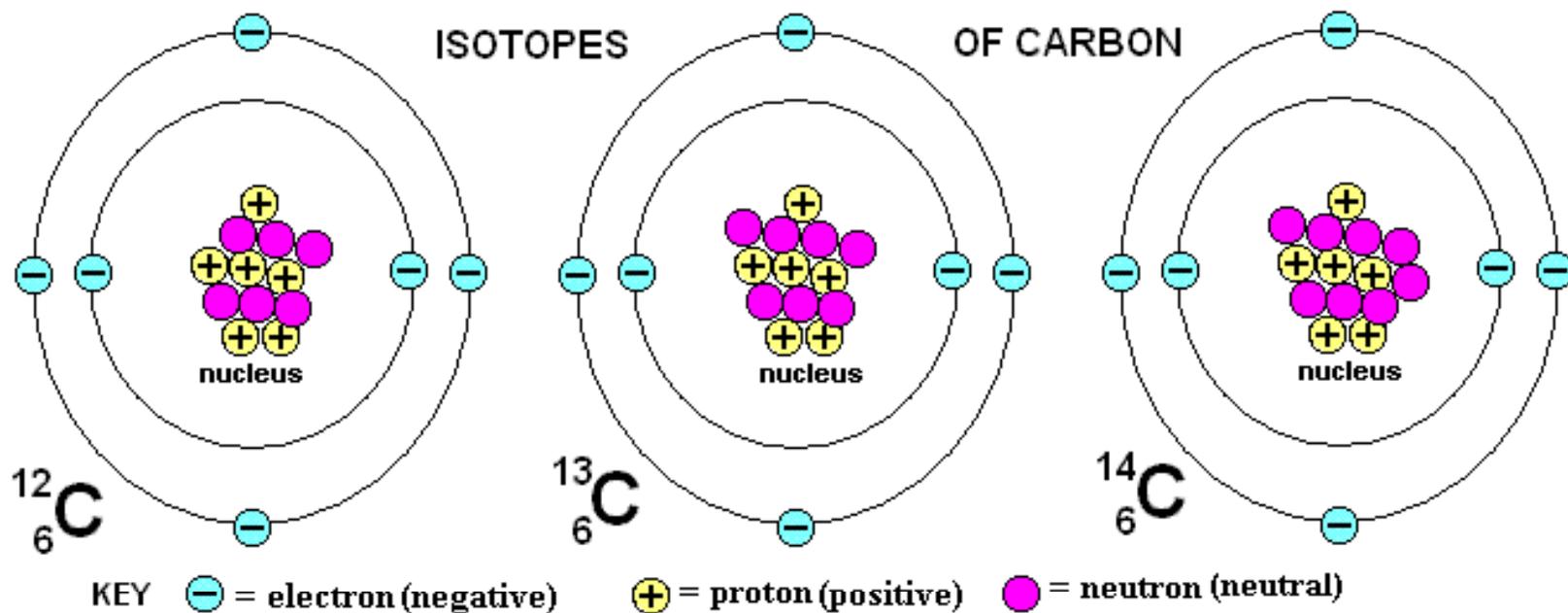
Gli isotopi di uno stesso elemento (es. ^{12}C , ^{13}C , ^{14}C) hanno **quasi** le stesse caratteristiche chimiche.

Per questo motivo si comportano in modo **quasi** identico nei processi di formazione dei minerali che compongono le rocce, nei processi biologici, nei fenomeni atmosferici etc.

(eccezione notevole sono gli isotopi dell'idrogeno)

Tuttavia, le differenze di massa daranno come risultato la **parziale separazione** degli isotopi leggeri da quelli pesanti nel corso di processi chimici e fisici (es. diffusione, evaporazione).

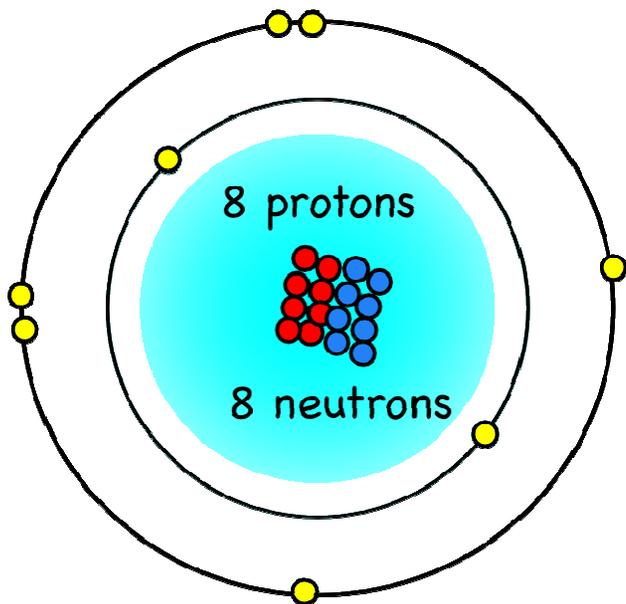
Questo processo si chiama **frazionamento isotopico** ([en. isotope fractionation](#)).



mass number \rightarrow 12 **C**
 (A)

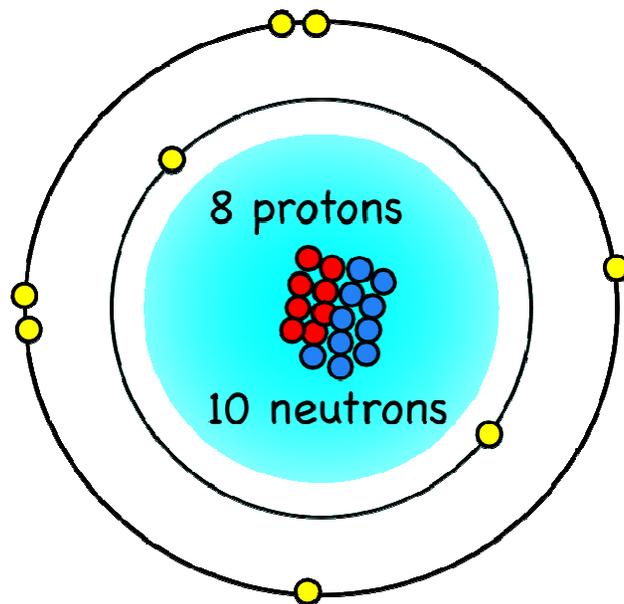
atomic number \rightarrow 6 **C**
 (Z)

Oxygen-16



atomic mass = 18

Oxygen-18



atomic mass = 18

Gli isotopi sono considerati stabili (*en. stable*) o non stabili (*en. unstable*); detti anche isotopi radioattivi

Il concetto di stabilità non è netto.

Esistono infatti isotopi "quasi stabili": cioè, pur essendo radioattivi, hanno un tempo di dimezzamento estremamente lungo anche se confrontato con l'età della Terra di 4.5 Ga.

Teorie recenti ipotizzano che nessun isotopo è da ritenersi propriamente stabile.

Nella prima parte del corso ci occuperemo degli isotopi stabili.

Conseguenze del **frazionamento isotopico**: in natura gli elementi chimici sono rappresentati da più di un isotopo, ossia come una **miscela isotopica** (en. [isotope mixture](#)), la cui composizione varia in funzione dei fenomeni idro-geochimici o biologici che hanno determinato tale miscela.

Esempio: il carbonio in natura è una miscela di tre isotopi, ^{12}C , ^{13}C e ^{14}C .

Rispetto alla quantità globale di carbonio:

^{12}C - 98,89%

^{13}C - 1,11%,

^{14}C – in tracce (1 atomo ogni $\sim 10^{12}$ atomi di ^{12}C ; radioattivo).

English reading:

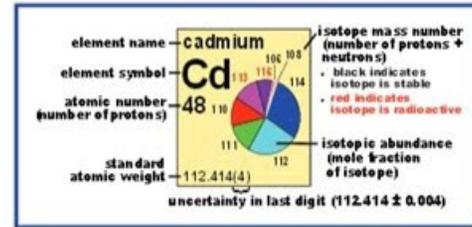
^{12}C carbon twelve, ^{13}C carbon thirteen, ^{14}C carbon fourteen.

IUPAC Periodic Table of the Isotopes

Element Background Color Key

Standard atomic weights are the best estimates by IUPAC of atomic weights that are found in normal materials, which are terrestrial materials that are reasonably possible sources for elements and their compounds in commerce, industry, or science. They are determined using all stable isotopes and selected radioactive isotopes (having relatively long half-lives and characteristic terrestrial isotopic compositions). Isotopes are considered stable (non-radioactive) if evidence for radioactive decay has not been detected experimentally.

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1 hydrogen H 1 (1.007 84, 1.008 11)																	18 helium He 2 4.002 602(2)
2 lithium Li 3 (6.938, 6.997)	beryllium Be 4 9.012 183(5)																
sodium Na 11 22.989 769 28(2)	magnesium Mg 12 (24.304, 24.307)																
3 potassium K 19 39.0983(1)	4 calcium Ca 20 40.078(4)	5 scandium Sc 21 44.955 908(5)	6 titanium Ti 22 47.867(1)	7 vanadium V 23 50.9415(1)	8 chromium Cr 24 51.996 16(5)	9 manganese Mn 25 54.938 044(3)	10 iron Fe 26 55.845(2)	11 cobalt Co 27 58.933 196(4)	12 nickel Ni 28 58.693 4(4)	13 copper Cu 29 63.546(3)	14 zinc Zn 30 65.38(2)	15 gallium Ga 31 69.723(1)	16 germanium Ge 32 72.630(8)	17 arsenic As 33 74.921 535(6)	18 selenium Se 34 78.9718(5)	19 bromine Br 35 (79.901, 79.907)	20 krypton Kr 36 83.798(2)
37 rubidium Rb 85.467 8(2)	38 strontium Sr 87.62(1)	39 yttrium Y 88.905 84(2)	40 zirconium Zr 91.224(2)	41 niobium Nb 92.906 37(2)	42 molybdenum Mo 95.94(1)	43 technetium Tc []	44 ruthenium Ru 101.07(2)	45 rhodium Rh 102.905 50(2)	46 palladium Pd 106.42(1)	47 silver Ag 107.868 2(2)	48 cadmium Cd 112.414(4)	49 indium In 114.818(1)	50 tin Sn 118.710(7)	51 antimony Sb 121.750(1)	52 tellurium Te 127.60(3)	53 iodine I 126.904 47(3)	54 xenon Xe 131.29(6)
55 caesium Cs 132.905 451 36(6)	56 barium Ba 137.327(7)	57 - 71 lanthanoids	72 hafnium Hf 178.49(2)	73 tantalum Ta 180.947 88(2)	74 tungsten W 183.84(1)	75 rhenium Re 186.207(1)	76 osmium Os 190.23(2)	77 iridium Ir 192.227(3)	78 platinum Pt 195.084(5)	79 gold Au 196.966 53(5)	80 mercury Hg 200.59(2)	81 thallium Tl 204.38(2), 204.38(1)	82 lead Pb 207.2(1)	83 bismuth Bi 208.980 40(1)	84 polonium Po []	85 astatine At []	86 radon Rn []
87 francium Fr []	88 radium Ra []	89 - 103 actinoids	104 rutherfordium Rf []	105 dubnium Db []	106 seaborgium Sg []	107 bohrium Bh []	108 hassium Hs []	109 meitnerium Mt []	110 darmstadtium Ds []	111 roentgenium Rg []	112 copernicium Cn []	113 ununtrium Uut []	114 flerovium Fl []	115 ununpentium Uup []	116 livermorium Lv []	117 ununseptium Uus []	118 ununoctium Uuo []

57 lanthanum La 138.905 47(7)	58 cerium Ce 140.116(1)	59 praseodymium Pr 140.907 65(2)	60 neodymium Nd 144.242(2)	61 promethium Pm []	62 samarium Sm 150.36(2)	63 europium Eu 151.964(1)	64 gadolinium Gd 157.25(3)	65 terbium Tb 158.925 38(2)	66 dysprosium Dy 162.500(1)	67 holmium Ho 164.930 33(2)	68 erbium Er 167.259(3)	69 thulium Tm 168.934 22(2)	70 ytterbium Yb 173.054(5)	71 lutetium Lu 174.967(1)
89 actinium Ac []	90 thorium Th 232.0377(4)	91 protactinium Pa 231.036 2(8)	92 uranium U 238.028 91(3)	93 neptunium Np []	94 plutonium Pu []	95 americium Am []	96 curium Cm []	97 berkelium Bk []	98 californium Cf []	99 einsteinium Es []	100 fermium Fm []	101 mendelevium Md []	102 nobelium No []	103 lawrencium Lr []

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element name: cadmium
 element symbol: Cd
 atomic number: 48
 number of protons: 48
 standard atomic weight: 112.414(4)
 uncertainty in last digit: (112.414 ± 0.004)



isotope mass number (number of protons + neutrons):
 • black indicates isotope is stable
 • red indicates isotope is radioactive

isotopic abundance (mole fraction of isotope)

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1	Hydrogen	1	Helium	2
3	Lithium	3	Beryllium	4
5	Boron	5	Carbon	6
7	Nitrogen	7	Oxygen	8
9	Fluorine	9	Neon	10
11	Sodium	11	Magnesium	12
13	Aluminum	13	Silicon	14
15	Phosphorus	15	Sulfur	16
17	Chlorine	17	Argon	18
19	Potassium	19	Calcium	20
21	Scandium	21	Titanium	22
23	Vanadium	23	Chromium	24
25	Manganese	25	Iron	26
27	Cobalt	27	Nickel	28
29	Copper	29	Zinc	30
31	Gallium	31	Germanium	32
33	Arsenic	33	Selenium	34
35	Bromine	35	Krypton	36
37	Rubidium	37	Strontium	38
39	Yttrium	39	Zirconium	40
41	Niobium	41	Niobium	41
43	Rhodium	43	Palladium	42
45	Rhodium	45	Cadmium	44
47	Silver	47	Indium	45
49	Copper	49	Tin	46
51	Antimony	51	Lead	47
53	Iodine	53	Bismuth	48
55	Cesium	55	Polonium	49
57	Francium	57	Astatine	50
59	Francium	59	Radon	51
61	Actinium	61	Radon	52
63	Actinium	63	Radon	53
65	Actinium	65	Radon	54
67	Actinium	67	Radon	55
69	Actinium	69	Radon	56
71	Actinium	71	Radon	57
73	Actinium	73	Radon	58
75	Actinium	75	Radon	59
77	Actinium	77	Radon	60
79	Actinium	79	Radon	61
81	Actinium	81	Radon	62
83	Actinium	83	Radon	63
85	Actinium	85	Radon	64
87	Actinium	87	Radon	65
89	Actinium	89	Radon	66
91	Actinium	91	Radon	67
93	Actinium	93	Radon	68
95	Actinium	95	Radon	69
97	Actinium	97	Radon	70
99	Actinium	99	Radon	71
101	Actinium	101	Radon	72
103	Actinium	103	Radon	73
105	Actinium	105	Radon	74
107	Actinium	107	Radon	75
109	Actinium	109	Radon	76
111	Actinium	111	Radon	77
113	Actinium	113	Radon	78
115	Actinium	115	Radon	79
117	Actinium	117	Radon	80
119	Actinium	119	Radon	81
121	Actinium	121	Radon	82
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515	Actinium	515	Radon	279
517	Actinium	517		

IUPAC Periodic Table of the Isotopes

Element Background Color Key

Standard atomic weights are the best estimates by IUPAC of atomic weights that are found in normal materials, which are terrestrial materials that are reasonably possible sources for elements and their compounds in commerce, industry, or science. They are determined using all stable isotopes and selected radioactive isotopes having relatively long half-lives and characteristic terrestrial isotopic compositions. Isotopes are considered stable (non-radioactive) if evidence for radioactive decay has not been detected experimentally.

-  Element has two or more isotopes that are used to determine its standard atomic weight. The isotopic abundances and atomic weights vary in normal materials. These variations are well known, and the standard atomic weight is given as lower and upper bounds within square brackets, [].
-  Element has two or more isotopes that are used to determine its standard atomic weight. The isotopic abundances and atomic weights vary in normal materials, but upper and lower bounds of the standard atomic weight have not been assigned by IUPAC or the variations may be too small to affect the standard atomic weight value significantly. Thus, the standard atomic weight is given as a single value with an uncertainty that includes both measurement uncertainty and uncertainty due to isotopic abundance variations.
-  Element has only one isotope that is used to determine its standard atomic weight. Thus, the standard atomic weight is invariant and is given as a single value with an IUPAC evaluated uncertainty.

element name — cadmium
 element symbol — Cd
 atomic number (number of protons) — 48
 standard atomic weight — 112.414(4)
 uncertainty in last digit (112.414 ± 0.004)

isotope mass number (number of protons + neutrons)
 • black indicates isotope is stable
 • red indicates isotope is radioactive

isotopic abundance (mole fraction of isotope)

1 hydrogen H 1.007 84(7)	2 helium He 4.002 602(2)
3 lithium Li 6.94(1)	4 beryllium Be 9.012 182(2)
5 boron B 10.81(1)	6 carbon C 12.010 7(8)
7 nitrogen N 14.006 4(4)	8 oxygen O 15.999 0319(6)
9 fluorine F 18.998 4032(3)	10 neon Ne 20.179 7(6)
11 sodium Na 22.989 769 28(2)	12 magnesium Mg 24.304(6)
13 aluminum Al 26.981 538 6(3)	14 silicon Si 28.085 5(3)
15 phosphorus P 30.973 761 5(2)	16 sulfur S 32.06(5)
17 chlorine Cl 35.45(3)	18 argon Ar 39.948(1)
19 potassium K 39.098 3(1)	20 calcium Ca 40.078(4)
21 scandium Sc 44.955 912(5)	22 titanium Ti 47.88(7)
23 vanadium V 50.941 5(5)	24 chromium Cr 51.996 1(6)
25 manganese Mn 54.938 045(3)	26 iron Fe 55.845(2)
27 cobalt Co 58.933 195(5)	28 nickel Ni 58.69(3)
29 copper Cu 63.546(3)	30 zinc Zn 65.38(4)
31 gallium Ga 69.723(1)	32 germanium Ge 72.63(1)
33 arsenic As 74.921 6(2)	34 selenium Se 78.971 8(8)
35 bromine Br 79.904(1)	36 krypton Kr 83.798(4)
37 rubidium Rb 85.467 8(3)	38 strontium Sr 87.62(1)
39 yttrium Y 88.905 84(2)	40 zirconium Zr 91.224(2)
41 niobium Nb 92.906 38(2)	42 molybdenum Mo 95.94(1)
43 technetium Tc [98]	44 ruthenium Ru 101.07(2)
45 rhodium Rh 102.905 5(3)	46 palladium Pd 106.905 09(2)
47 silver Ag 107.868 2(2)	48 cadmium Cd 112.414(4)
49 copper Cu 107.868 2(2)	50 mercury Hg 200.59(2)
51 antimony Sb 121.757(3)	52 tellurium Te 127.6(3)
53 iodine I 126.904 47(3)	54 xenon Xe 131.29(4)
55 cesium Cs 132.905 451(6)	56 barium Ba 137.327(2)
57 - 71 lanthanoids	57 - 71 actinoids
72 hafnium Hf 178.49(6)	73 tantalum Ta 180.947 88(2)
74 tungsten W 183.84(1)	75 rhenium Re 186.207(2)
76 osmium Os 190.23(4)	77 iridium Ir 192.222(1)
78 platinum Pt 195.084(2)	79 gold Au 196.966 569(4)
80 mercury Hg 200.59(2)	81 thallium Tl 204.38(3)
82 lead Pb 207.2(1)	83 bismuth Bi 208.980 4(1)
84 polonium Po [209]	85 astatine At [210]
86 radon Rn [222]	87 - 103 actinoids

element name — cadmium
 element symbol — Cd
 atomic number (number of protons) — 48
 standard atomic weight — 112.414(4)
 uncertainty in last digit (112.414 ± 0.004)

isotope mass number (number of protons + neutrons)
 • black indicates isotope is stable
 • red indicates isotope is radioactive

isotopic abundance (mole fraction of isotope)

lanthanum La 57 138.905 47(3)	cerium Ce 58 140.12(1)	praseodymium Pr 59 140.907 65(3)	neodymium Nd 60 144.24(1)	promethium Pm 61 [145]	samarium Sm 62 150.36(2)	europium Eu 63 151.964(1)	gadolinium Gd 64 157.25(1)	terbium Tb 65 158.925 34(5)	dysprosium Dy 66 162.500 13(2)	holmium Ho 67 164.930 32(2)	erbium Er 68 167.259 3(2)	thulium Tm 69 168.930 4(2)	ytterbium Yb 70 173.054 7(1)	lutetium Lu 71 174.967(1)
actinium Ac 89 [227]	thorium Th 90 232.037 7(4)	protactinium Pa 91 231.036 2(1)	uranium U 92 238.028 91(3)	neptunium Np 93 [237]	plutonium Pu 94 [244]	americium Am 95 [243]	curium Cm 96 [247]	berkelium Bk 97 [247]	californium Cf 98 [251]	einsteinium Es 99 [252]	fermium Fm 100 [257]	mendelevium Md 101 [258]	nobelium No 102 [259]	lawrencium Lr 103 [260]



Lead isotopes in silver reveal earliest Phoenician quest for metals in the west Mediterranean

Tzila Eshel^{a,b,c,1}, Yigal Erel^{c,1}, Naama Yahalom-Mack^d, Ofir Tirosh^c, and Ayelet Gilboa^{a,b}

^aZinman Institute of Archaeology, University of Haifa, Haifa 3498838, Israel; ^bDepartment of Archaeology, University of Haifa, Haifa 3498838, Israel; ^cThe Fredy and Nadine Herrmann Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel; and ^dInstitute of Archaeology, The Hebrew University of Jerusalem, Jerusalem 9190501, Israel

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When and why did the Phoenicians initiate long-term connections between the Levant and western Europe?

ACRONIMI: LI = Lead isotopes

<http://oxalid.arch.ox.ac.uk/>

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Case Study

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OXALID : Oxford Archaeological Lead Isotope Database from the Isotrace Laboratory

Noël Harold Gale, MA, DSc, PhD, BSc, ARCS, FSA

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Stos-Gale, Z.A., Gale, N.H., Houghton, J. and Speakman, R. 1995. Lead isotope analyses of ores from the Western Mediterranean. *Archaeometry* 37, 2. 407-415.

We use **silver** to answer this question, presenting **the largest dataset of chemical and isotopic analyses of silver items from silver hoards found in Phoenician homeland sites.**

Intertwining **lead isotope analysis of silver items with precise archaeological context and chronology**, we provide analytical evidence for the onset of Phoenician westward expansion.

We suggest that **the quest for silver instigated a long, exploratory phase**, first in Anatolia (Asia Minor) and Sardinia, and subsequently in the Iberian Peninsula.

This **phase preceded the establishment of sustainable, flourishing Phoenician colonies in the West by over a century.**

In so doing, our results buttress the “**precolonization**” **theory**, accord it a firm chronological framework, and demonstrate that the quest for silver (and probably other metals) was an incentive for Phoenician westward expansion.

Furthermore, our results show that the Phoenicians introduced **innovative silver production methods to historic Europe.**

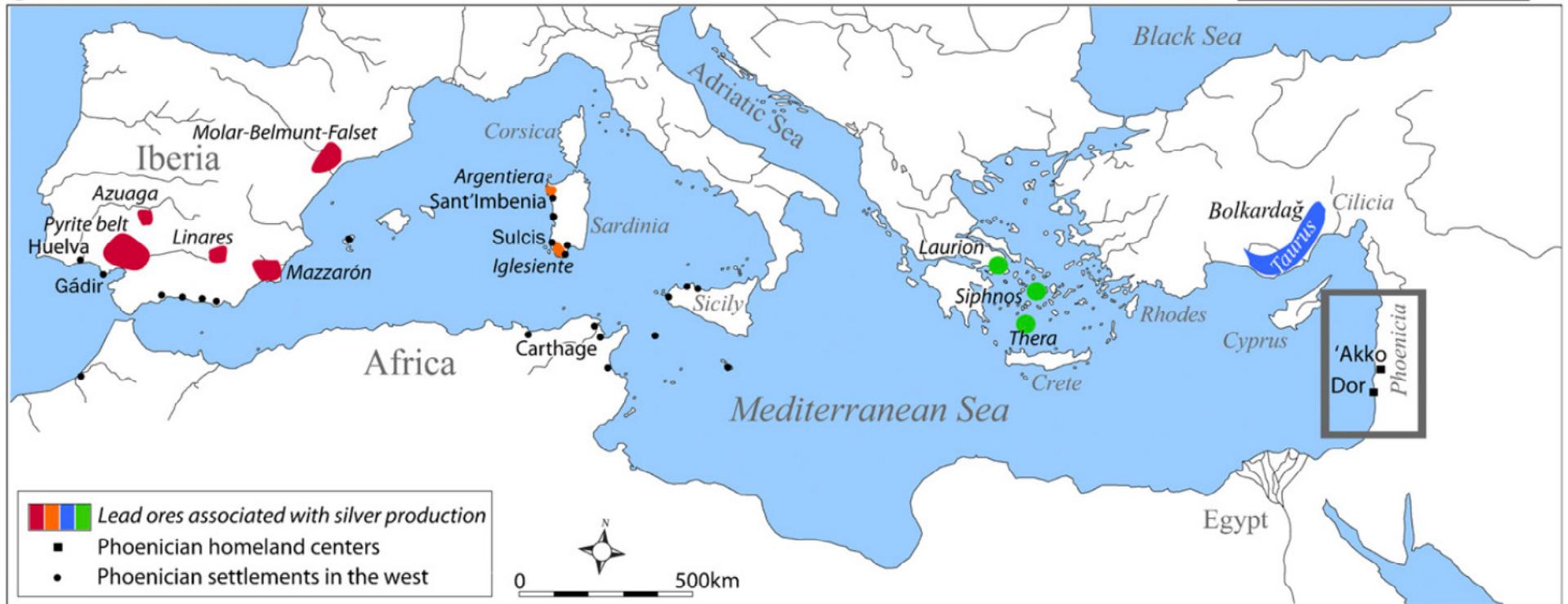
A

Hoard	Southern Levantine terminology	Approximate date BCE	Provenance
Dor	Early Iron Age IIA	2nd half of the 10th century BCE	Anatolia & Sardinia
'Akko	Iron Age IIA	10th-9th centuries BCE	Anatolia & Sardinia
'Ein Hofez	Late Iron Age IIA	9th century BCE	Iberia
Eshtemoa	Iron Age IIB	8th century BCE	Iberia

B



C



I materiali analizzati



A) Dor silver hoard image courtesy of the Collection of Israel Antiquities Authority © The Israel Museum

(B) 'Akko silver hoard image courtesy of Michael Eisenberg (photographer)

(C) 'Ein Hofez silver hoard image courtesy of the Collection of Israel Antiquities

RISULTATI

Dor (Second Half of the 10th Century BCE).

The first, striking observation regarding the Pb isotopic ratios of silver items from this hoard is that 10 out of 49 items have Pb isotopic compositions that plot outside the isotopic field of the Aegean–Anatolian ores.

This is the earliest known Levantine hoard displaying such isotopic values.

The Dor silver is a mixture of two major endmembers: Taurus (Anatolia) , and Cape Athinios (Thera, Cyclades, Aegean).

The second end member is consistent with ores from Iglesiente, southwest Sardinia, particularly the San Giovanni and Monteponi deposits

Hence....**the earliest evidence for western-Mediterranean silver in the Levant.**

RISULTATI

‘Akko (10th to 9th Centuries BCE).

The Pb isotopic ratios here resemble those of Dor, with two end members:

group 1, 6/22 silver items, consistent with the Bolkardağ valley (in the Taurus mountains) in Anatolia;

group 2, 5/22, with Sardinian ores (Iglesiente region).

The remainder are mixed (**groups 3 and 4**); group 3 (n = 2) has clear Sardinian isotopic contributions

The ‘Akko hoard, although dated with lesser resolution than the others, demonstrates that **the occurrence of Sardinian and Anatolian silver in early Iron Age Phoenicia was not episodic.**

RISULTATI

Ein Hofez (Ninth Century BCE).

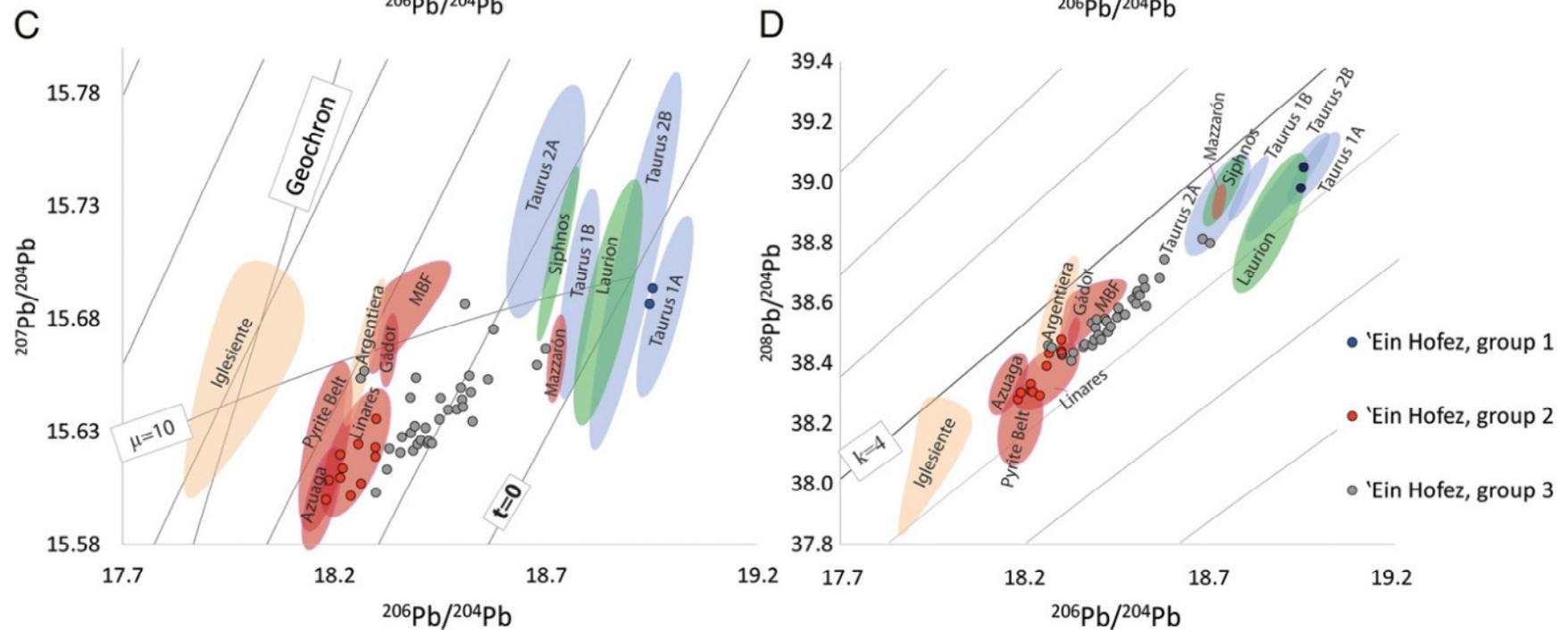
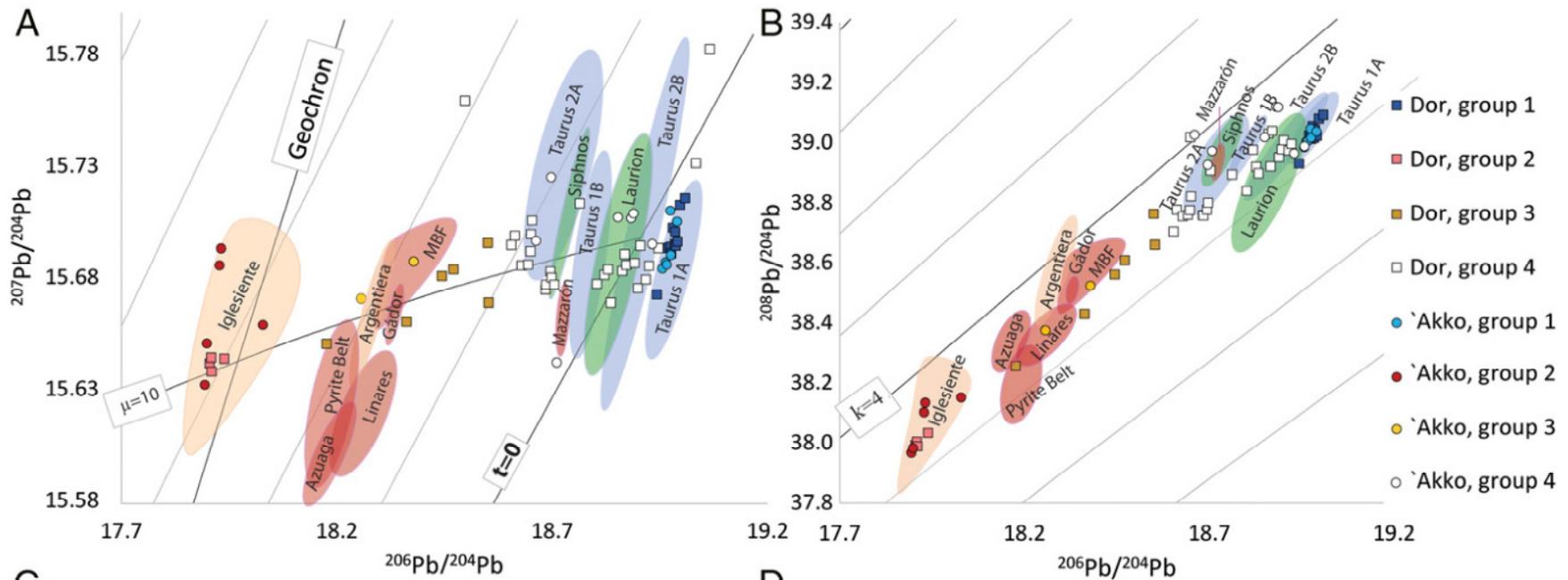
Only two items in this hoard are consistent with the Taurus isotopic field.

The other samples plot outside the isotopic field of the Aegean–Anatolian ores and are inconsistent with that of the Iglesias ores.

Group 2 (6/29 items) forms the other end member, and its isotopic values are consistent with Pb ores of Linares in Iberia.

The isotopic compositions of the remaining items (group 3; 21/29 items) plot between several Iberian Pb ores (in its south and west).

Thus, the 'Ein Hofez silver records the earliest phase of Phoenician presence there (see below). This suggests that **silver from Iberia continued to dominate the Levantine market for more than a century.**



Lead sources Sardinia Iberia Anatolia Aegean

CONCLUSIONI

The LI ratios of silver items in three hoards from southern Phoenicia provide evidence of Phoenician precolonization and early colonization and enable us to outline a geographic-temporal trajectory for the Phoenicians' far-flung quest for silver.

Second millennium BCE, silver reached the Levant from Anatolia/the Aegean

The earliest silver from the West, specifically from Sardinia's Iglesiente region, reached Phoenicia already during the second half of the 10th century BCE, well before permanent Phoenician settlements were established on the island or elsewhere in the West.

However, silver during this time still reached Phoenicia primarily from southeast Anatolia, continuing Bronze Age patterns.

Our results call for a reconsideration of the extent to which Phoenicians were involved in Anatolian silver production and commerce and suggest that the Phoenicians acquired their metallurgical know-how in Anatolia.

CONCLUSIONI

In the course of the ninth century BCE, Sardinian silver disappeared from the Phoenician hoards, and silver from Anatolia became scarce as well.

From this point onward, the Phoenician market was dominated by Iberian silver.

Our study shows that silver production there was at least as early as the first permanent Phoenician settlement on the peninsula. It certainly predates most of the Phoenician activity in southwest Iberia and demonstrates that silver exploitation in Iberia was a major goal from the outset.

So, when and why did the Phoenicians first traverse the vast expanses of sea between the shores of the Levant and the far West?

We answer: at least as early as the mid-10th century BCE, much earlier than any other current attestation, inter alia searching for silver.

The Phoenician expansion phenomenon should be revisited in light of these data.