

Selenium in Plants

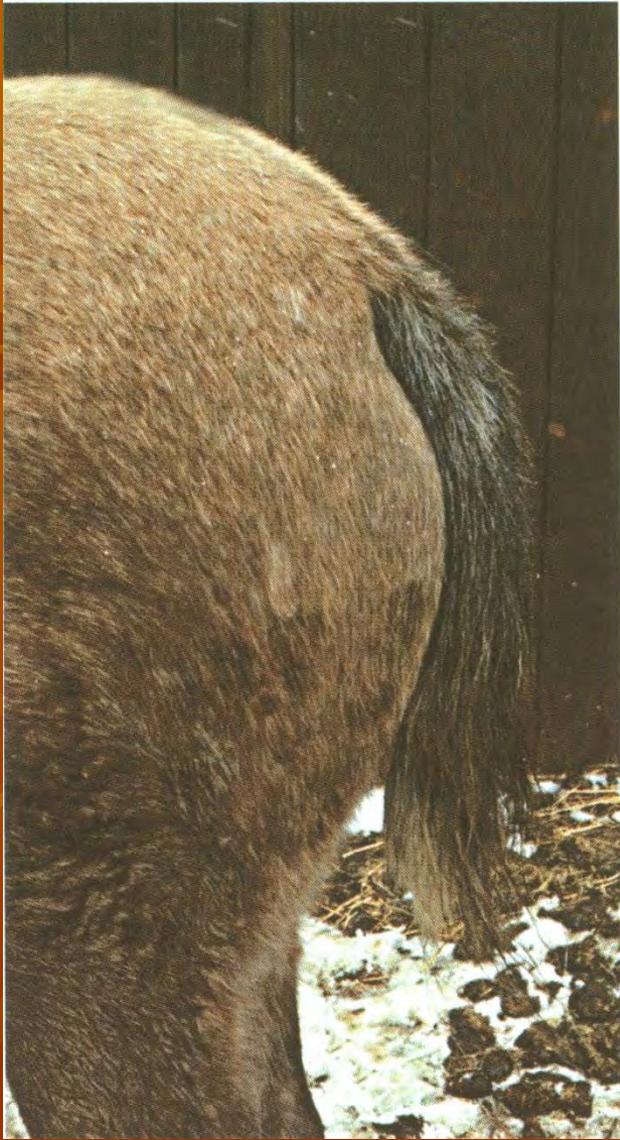
ADVS 5860/RLR 5860

March 2, 2010

T. Zane Davis

History

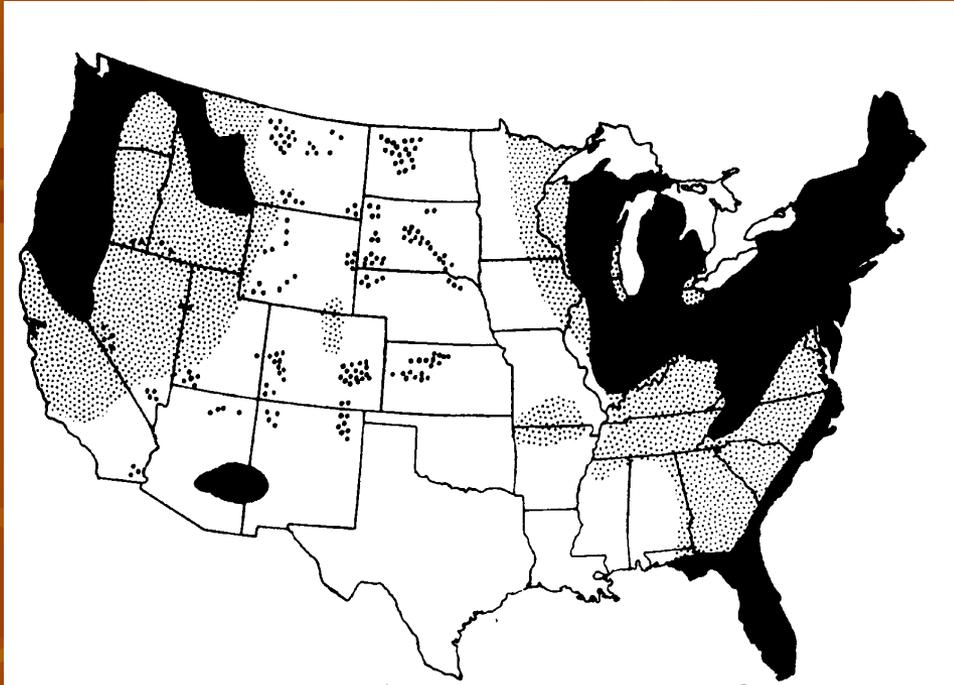
- 1295 Marco Polo in China
- 1857 Fort Randall in Nebraska (... inflammation, swelling and suppuration of the sheath, tenderness and inflammation of the feet, followed by suppuration at the point where the hoof joins the skin,, the hoof, in a measure, detaching itself, and a new one forming in its place...accompanied by loss of manes and tails...)
- 1907 and 1908- 15,000 sheep died in Medicine Bow, Wyoming



General Selenium Information

- Selenium is an essential nutrient for animals
- Deficiencies cause:
 - Immune system dysfunction
 - White Muscle Disease
 - Reproductive dysfunction
- Narrow window between deficiency and toxicity
 - < 0.1 ppm in forages may cause deficiency
 - > 5 ppm in forages may cause toxicity

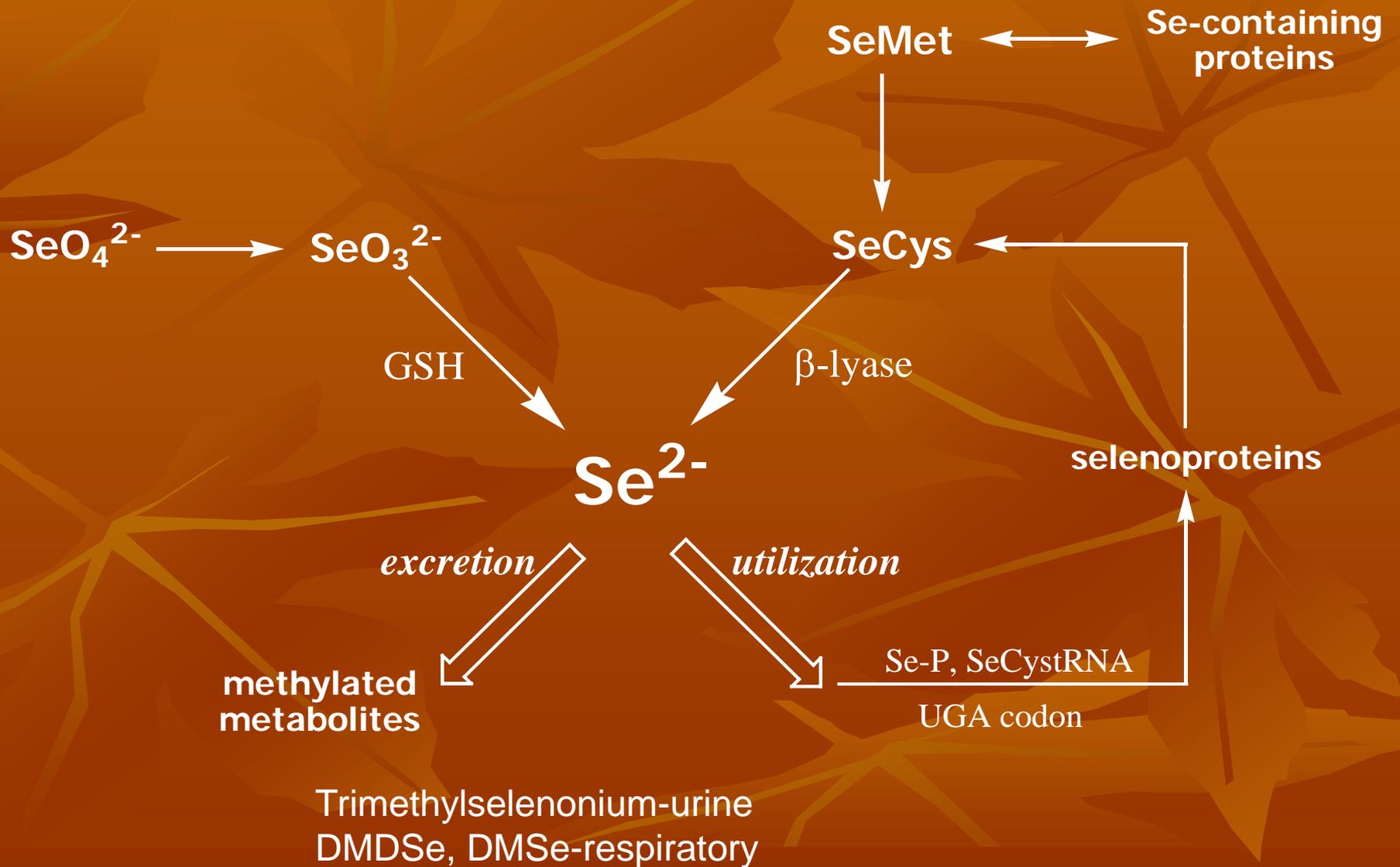
Selenium Distribution



- Black- low Se (<math><0.05\text{ ppm}</math>)
- White- variable Se (0.1 ppm)
- Black dots- Se Accumulators (>math>>50\text{ ppm}</math>)

Oxidation States of Selenium

- Se^{+6} Selenate- Na_2SeO_4 , SeO_3 , H_2SeO_4
- Se^{+4} Selenite- Na_2SeO_3 , SeO_2 , H_2SeO_3
- Se^0 Elemental Selenium
- Se^{-2} Selenide compounds



Selenium Accumulation

- Plants accumulate SOLUBLE selenium from the soil
 - Insoluble elemental selenium and selenides are NOT bioavailable to plants
- Selenium Indicator Plants
- Facultative Selenium Accumulators
- Passive Selenium Accumulators

Selenium Indicator Plants

- Referred to as OBLIGATE species
 - These species appear to require high selenium
 - Concentrations range from 1,000 to >13,000 ppm
- Specific indicators
 - *Astragalus* sp. (>20 different species)
 - *Xylorrhiza* sp. (asters)
 - *Oenopsis* sp. (goldenweed)
 - *Stanleya* sp. (prince's plume)

Astragalus
praelongus



Astragalus bisulcatus



Xylorrhiza glabriuscula



Stanleya pinnata



Facultative Selenium Accumulators

- Accumulate selenium when grown on high selenium soil
 - Do not require selenium for growth
 - Can grow just as well on low selenium soils
- Specific plants
 - *Aster* sp.
 - *Atriplex* sp. (saltbush)
 - *Sideranthus* sp.
 - *Machaeranthera* sp. (tansy asters)
 - *Grindelia* sp. (gumweed)

Grindelia squarrosa



Passive Selenium Accumulators

- Most other plant species
- High soluble soil selenium can be toxic to some plants
- Plants that have caused toxicosis
 - Numerous grasses
 - Cereal Grains
 - Numerous weeds
 - Etc.

Selenium content of plants

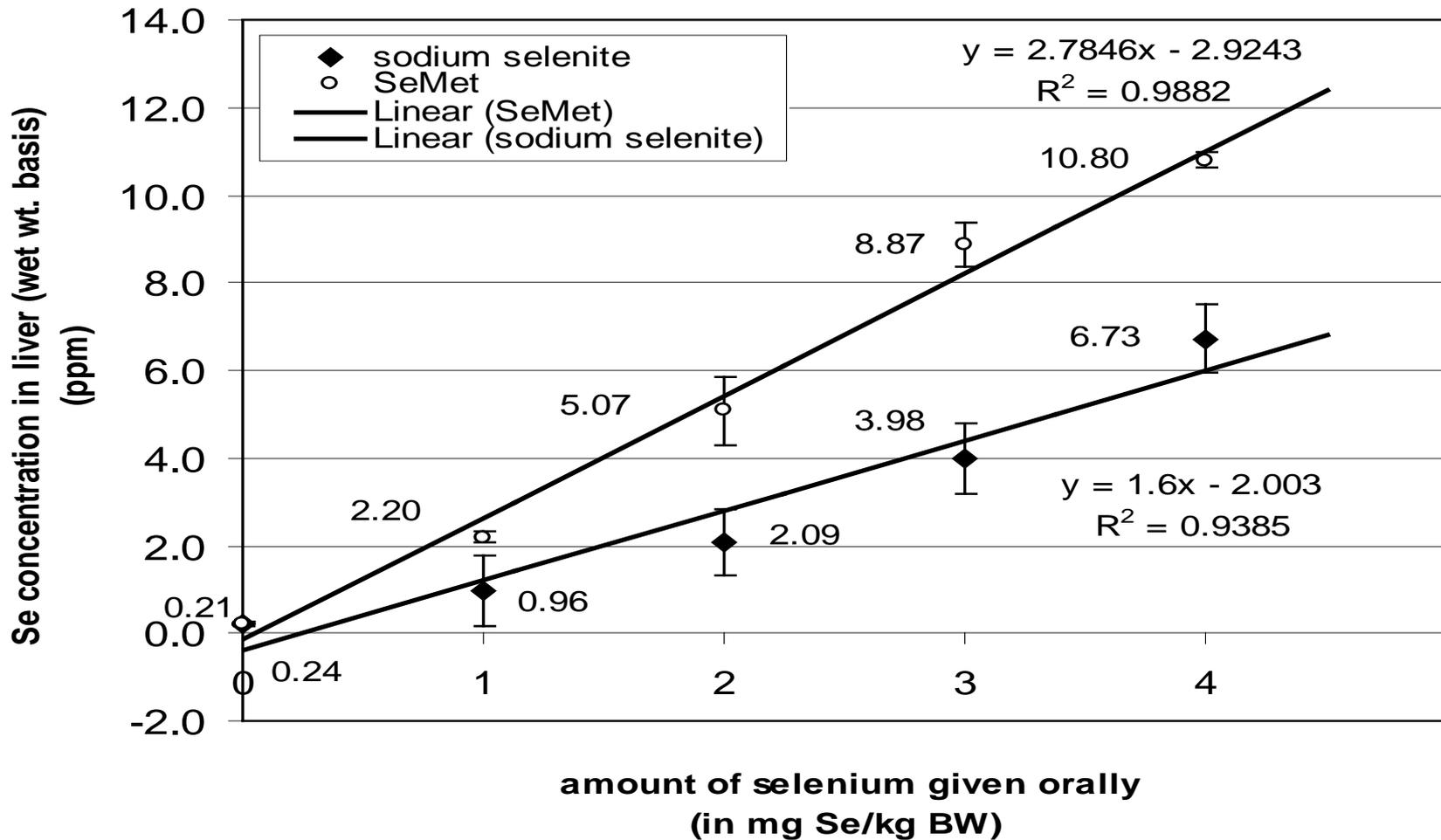
- Selenium Indicator Plants
 - Up to and in excess of 10,000 ppm
- Facultative Selenium Accumulators
 - < 0.1 ppm to few thousand ppm
- Passive Selenium Accumulators
 - < 0.1 ppm to a few hundred ppm

Form of Selenium in Plants

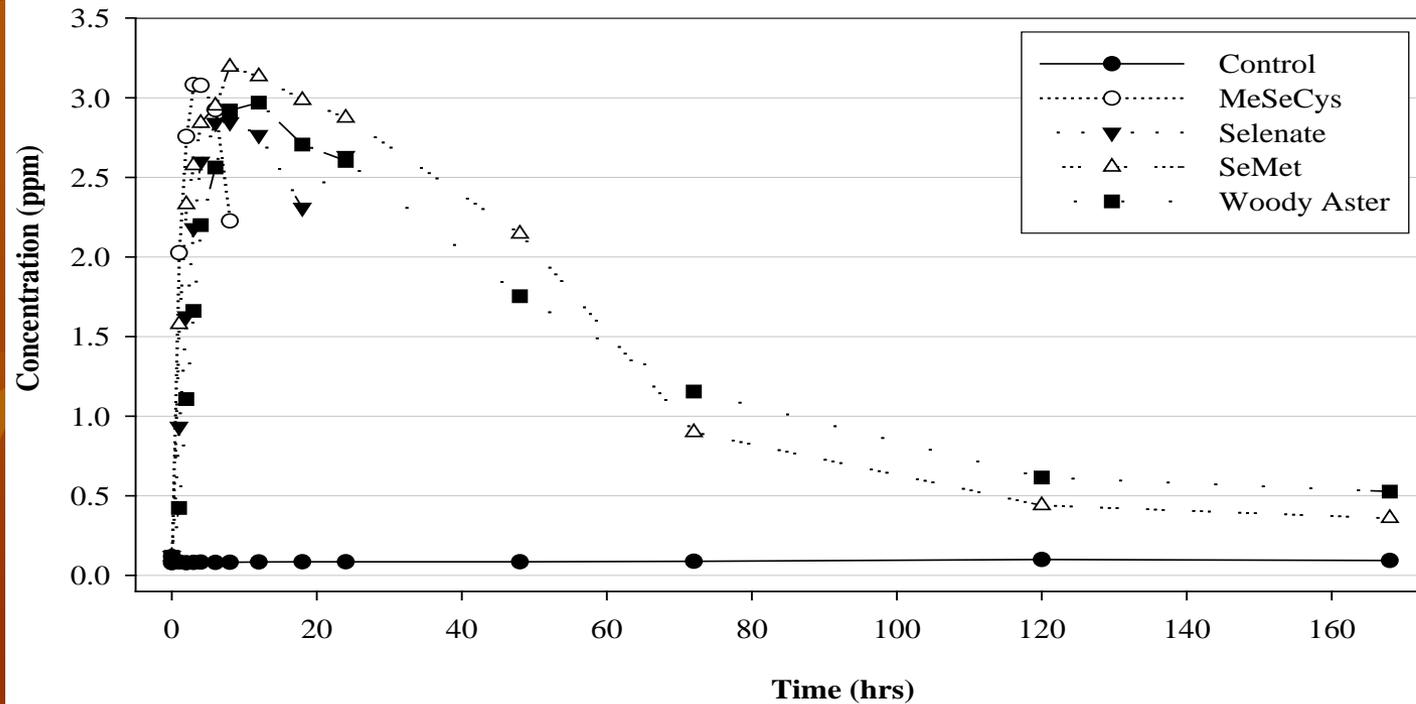
- Most Forages are Primarily Organic (> 80 to 98%)
 - Selenomethionine
 - Selenocysteine
 - Derivatives of the two above
 - Absorbed into animals via amino acid uptake channels
- Selenium Accumulator Plants
 - Selenate and Se-methylselenocysteine
 - Absorbed into animals via mineral uptake proteins
 - Absorbed into animal via amino acid uptake channels?

Inorganic vs. Organic

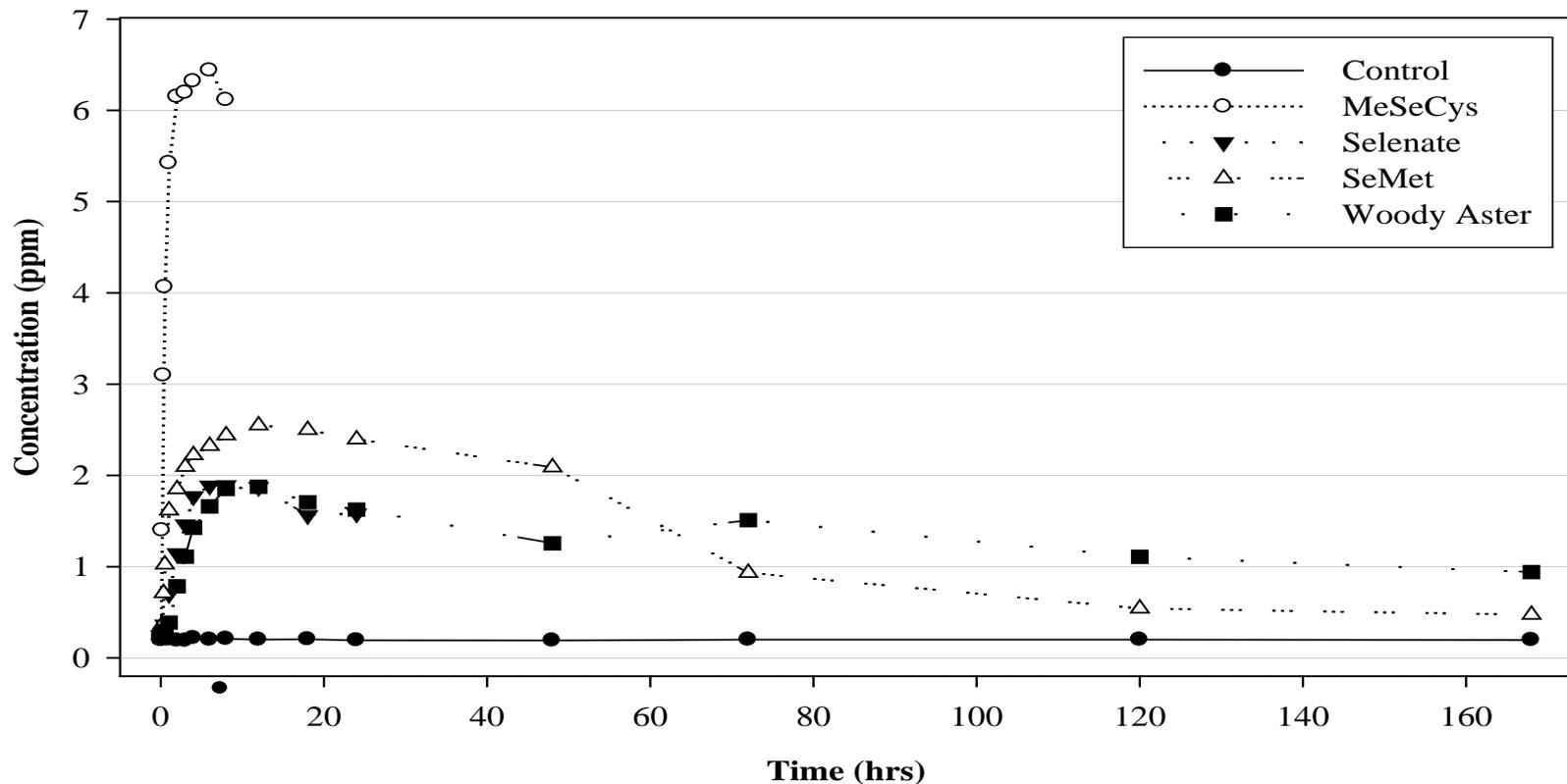
Selenium in sheep liver



Selenium concentration in serum of sheep dosed with various selenocompounds

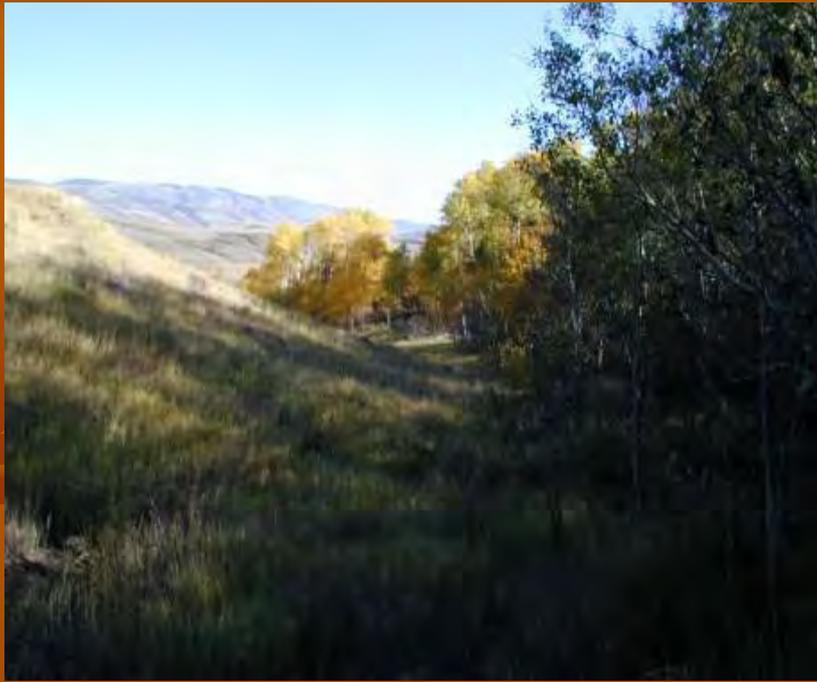


Selenium concentration in whole blood of sheep dosed with various selenocompounds



Selenium Toxicity

- Acute
 - > 0.5 to 1 mg Se/kg BW by injection
 - 1 to >10 mg Se/kg BW by ingestion
- Chronic
 - > 5 ppm Se in the total diet



Acute Selenium Poisoning

- Usually Obligate or Facultative Accumulators
- Clinical signs develop in a few hours to 1 day
 - Garlic like smell to the breath
 - Anorexia
 - Depression
 - Dyspnea
 - Recumbence
 - Coma
 - Death
- Death usually occurs within a few hours of signs

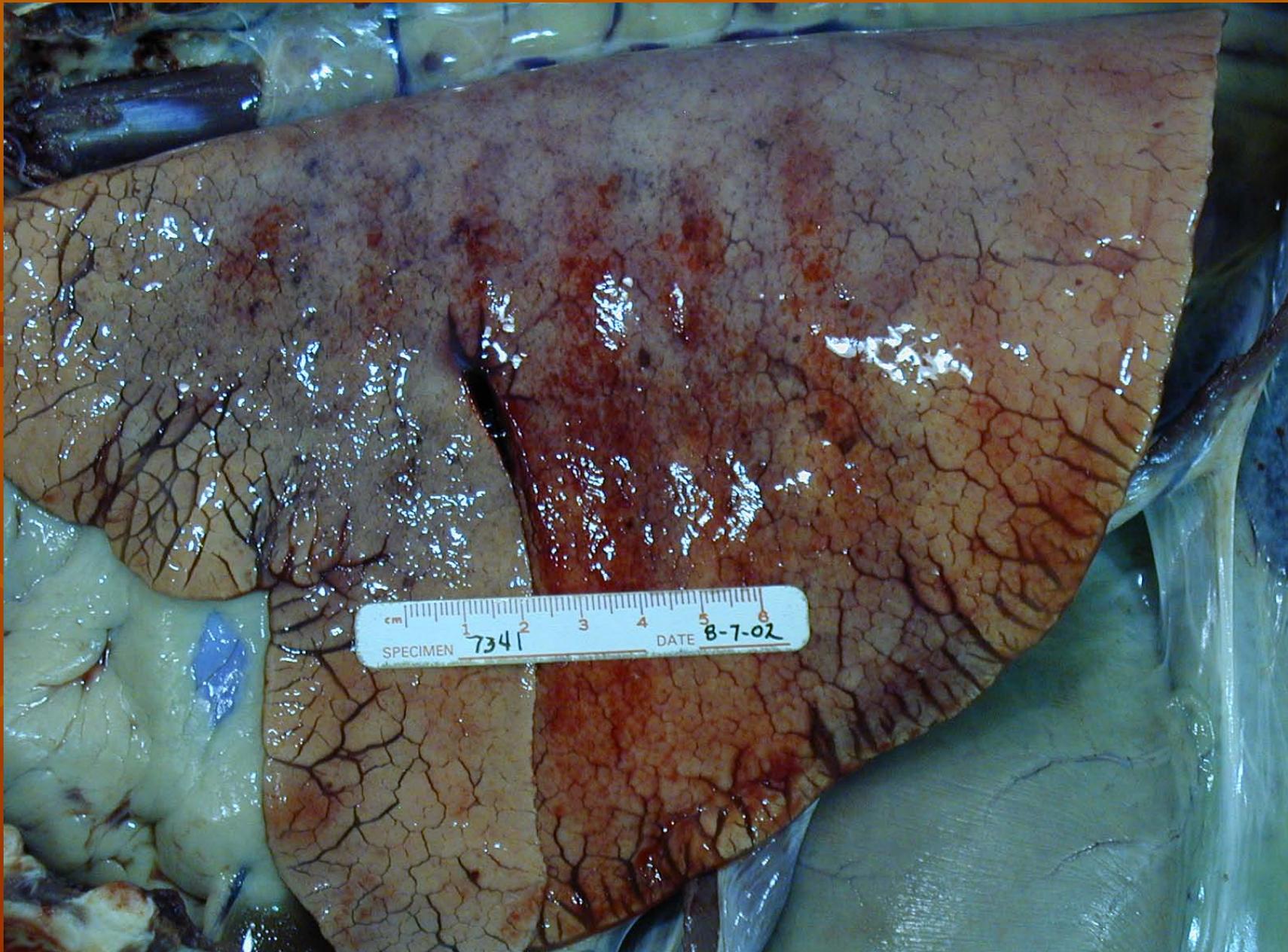


Chronic Selenium Poisoning

- Occurs after weeks of high selenium forage intake (> 5 to < 150 ppm)
- Once called “alkali disease” due to its association with alkaline soils
- Clinical Signs
 - Dullness
 - Hair loss
 - Lameness
 - Hoof and Joint Abnormalities
 - Anemia
 - Death due to starvation
- ??“Blind Staggers” – wandering, paralysis, dyspnea, death ??

Pathology

- Myocardial Necrosis
- Pulmonary Hemorrhage and Edema
- Passive Congestion
- +/- enteritis
- +/- systemic hemorrhage
- Hoof/joint lesions (chronic)
- Emaciation (chronic)



cm 1 2 3 4 5 6
SPECIMEN 7341 DATE 8-7-02



Possible Mechanisms of Selenium Toxicity

1. Substitution of selenium for sulfur.
2. Reaction between selenite and glutathione consumes or depletes cellular-free and protein-bound thiol levels.
3. Free radicals such as superoxide anions may be produced by the reactions of certain forms of Se with tissue thiols, causing oxidative injuries to tissues.

Selenium Interactions

- High selenium can cause deficiencies in other essential nutrients
 - Copper
 - Iron
 - Zinc

Sample Testing

- Liver
- Kidney
- Heart

- Rumen or Stomach Content

- Forages

- Water

Other Plant Minerals

- Sulfur

- Can cause polioencephalomalacia
- Can cause copper deficiency
- Can cause selenium deficiency

- Molybdenum

- Causes copper deficiency

Selenium suspected in cattle deaths near ID mine

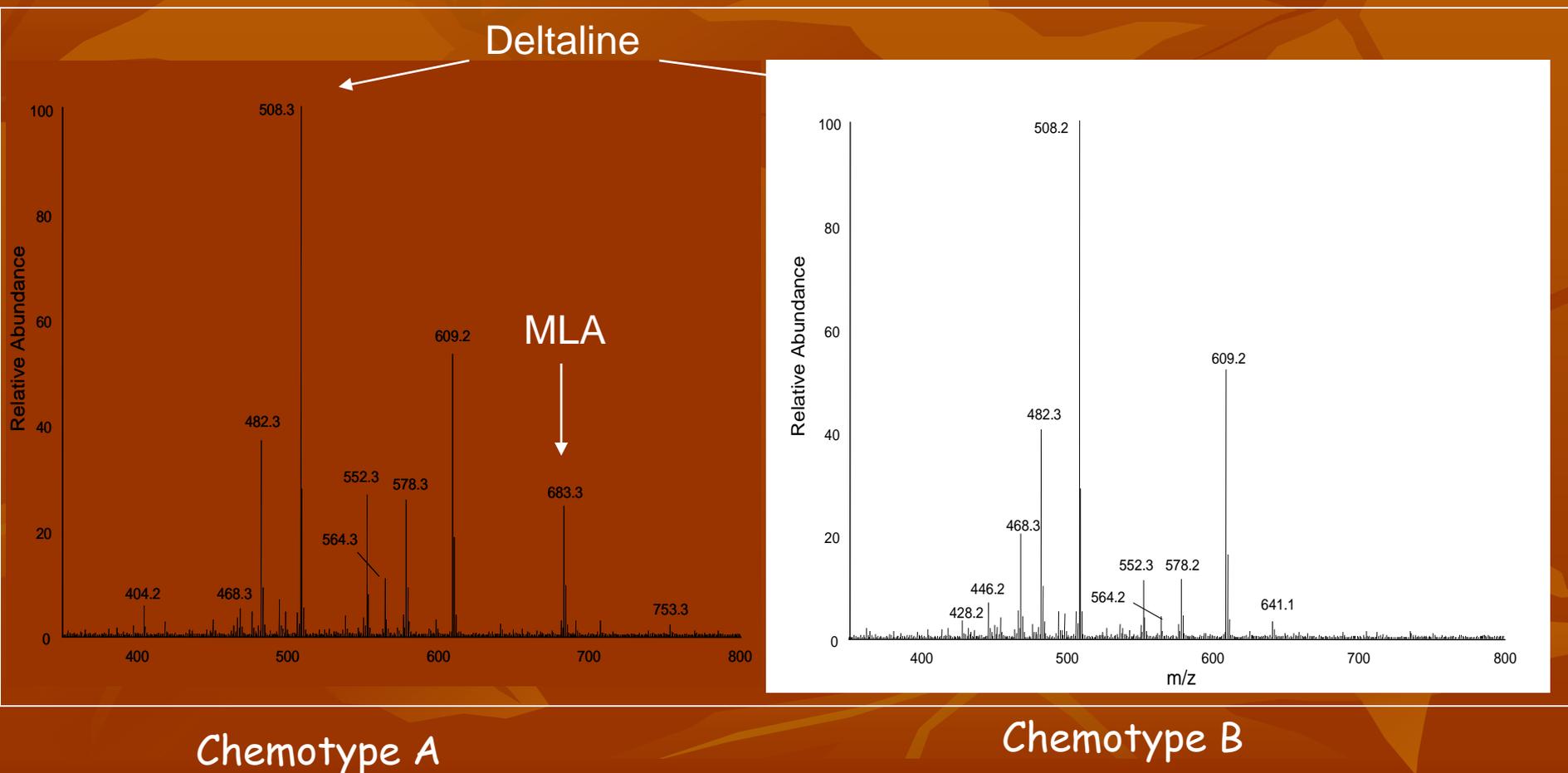
**By JOHN MILLER - Associated Press
Writer**

Published: 08/14/09

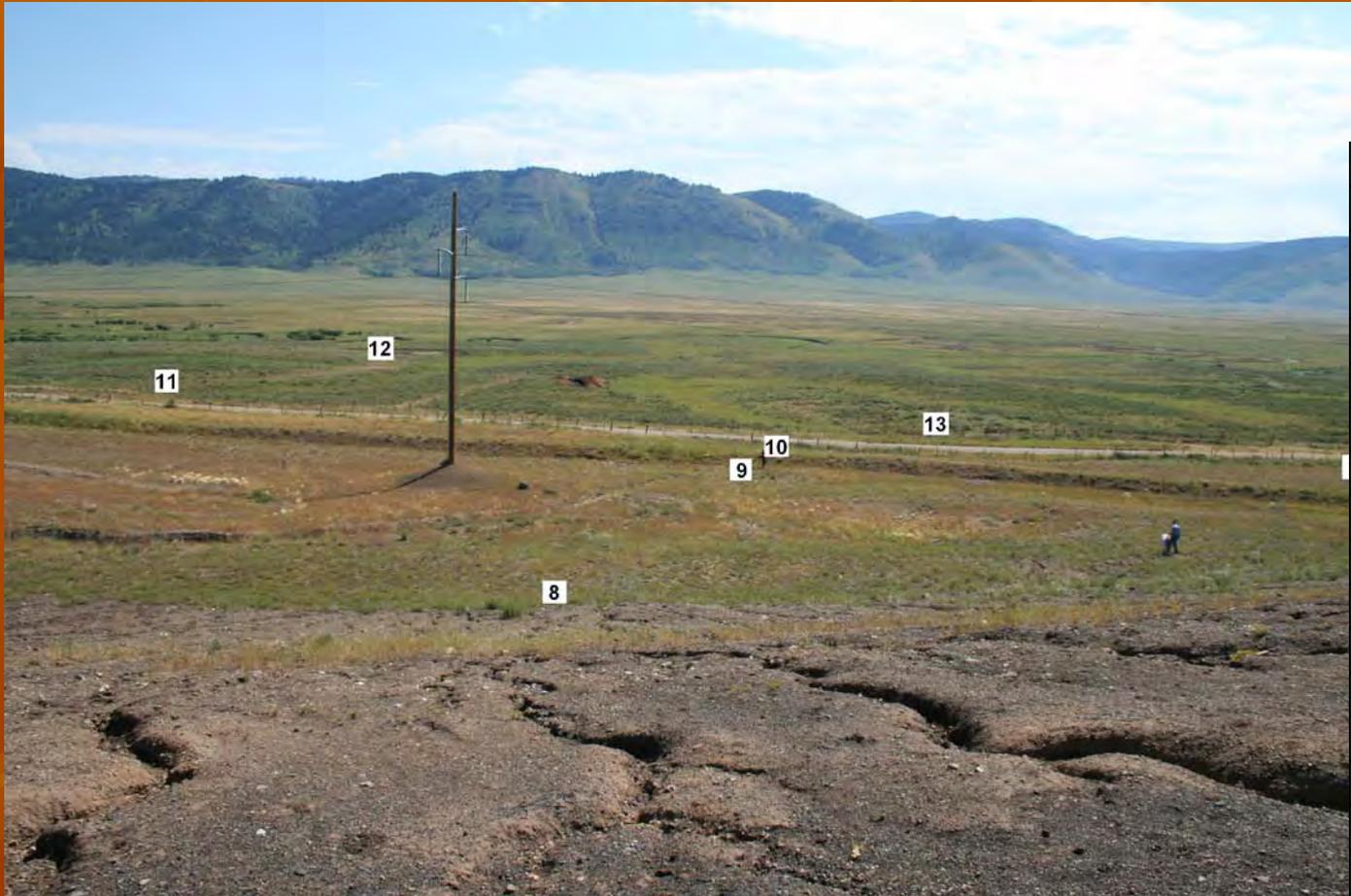
BOISE, Idaho — Eighteen cattle likely died of selenium poisoning near a southeastern Idaho phosphate mine, the latest livestock deaths in a region rich in phosphates where a legacy of pollution has killed horses and hundreds of sheep since the 1990s. The cattle died around Aug. 5 near the defunct Lanes Creek Mine. Fertilizer-maker J.R. Simplot Co. controls the mineral rights here, but says it's never actively mined the site. The dead cattle's livers showed high levels of selenium, a naturally occurring mineral unearthed with phosphate ore that contaminates groundwater and plants.



Electrospray mass spectra from samples representing each chemotype of *D. occidentale*



Lanes Creek mine site...



Site #	Plant	Se Conc. (ppm)
4	Alfalfa	291.34
4	Burnet	94.38
4	Clover	15.73
7	Burnet	316.31
7	Grass	291.34
7	Yarrow	232.03
7	Timothy	114.26
8	Aster	4360.48
8	Aster	4063.00
8	Aster	4059.51
8	Wheatgrass	182.03
8	Clover	155.63
8	Brome	155.49
9	Aster	941.49
11	Alfalfa	1.13
12	Clover	28.53
12	Aster	12.68
12	Water (in pond)	0.005
12	Water (below outlet)	0.005
13	Erigeron	1.66
13	Aster	1.53

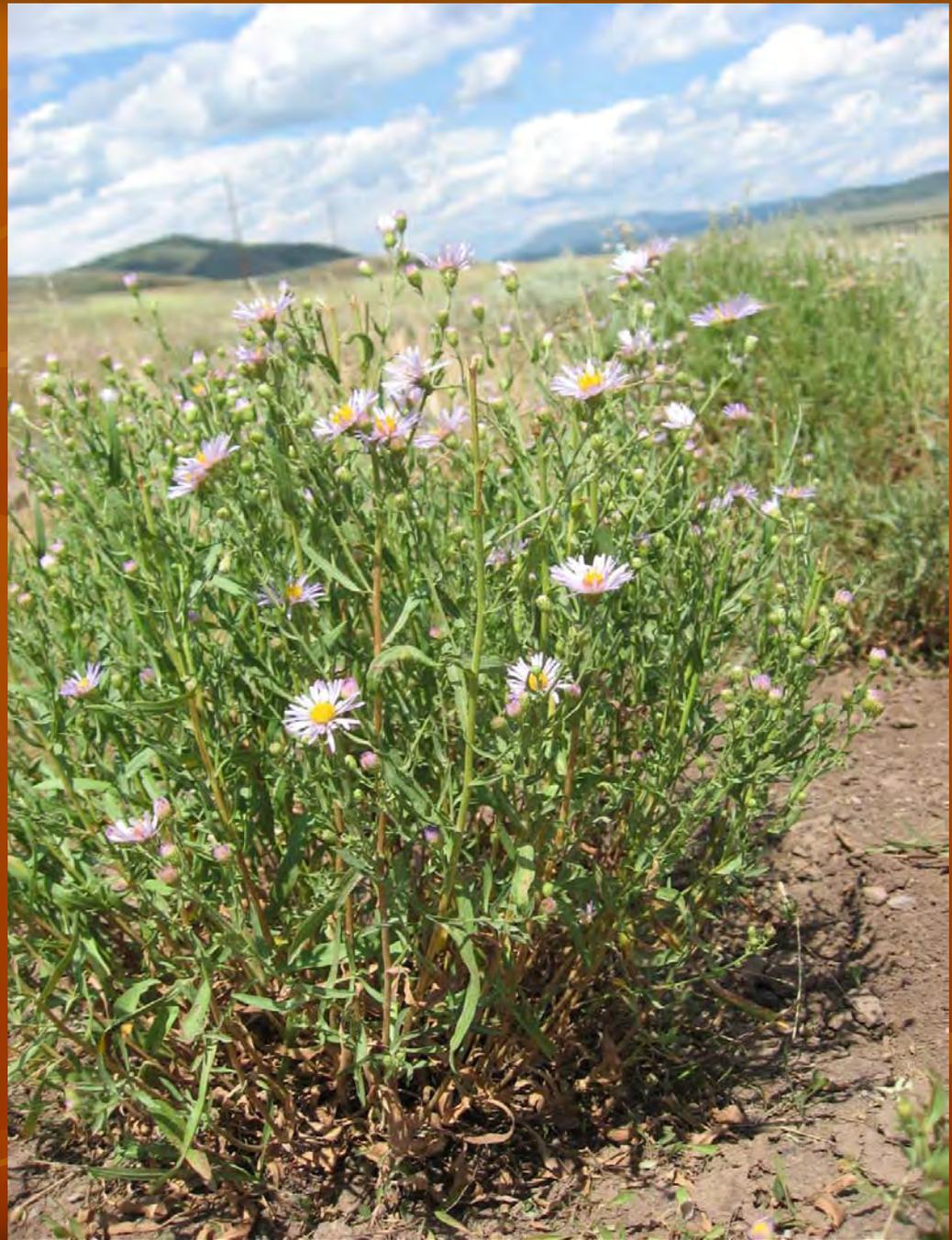


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Western Aster
(*Aster ascendens*)





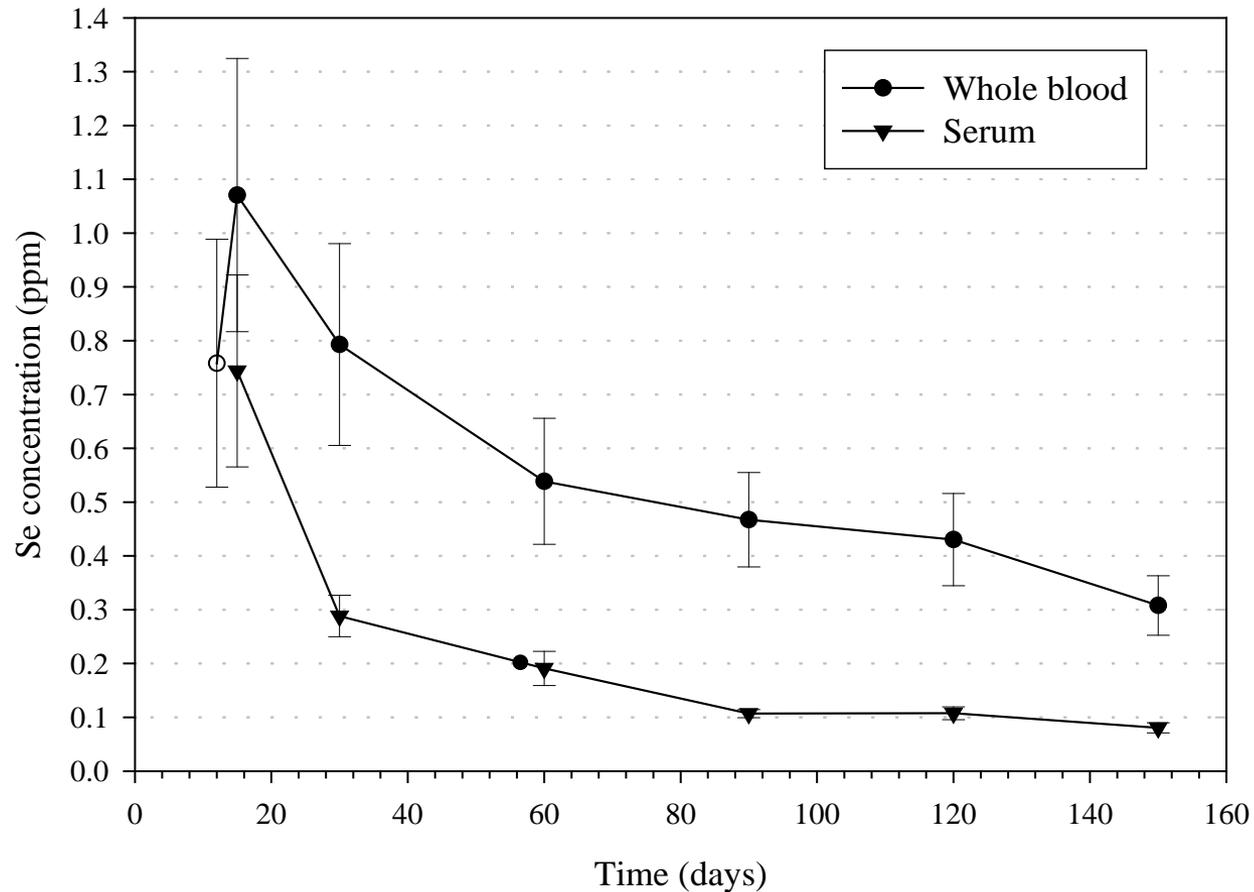
Tissue Se concentrations of steers that died from grazing Se-accumulator plants

Steer ID	Tissue (8/3/09)	Se conc. (ppm)	Normal Se conc. (ppm)
F54	Lung	0.760	~0.2
F54	Kidney	3.530	~1.0
F35	Lung	1.984	~0.2
F35	Kidney	3.286	~1.0
F35	Liver	8.983	0.25 - 0.50
F118	Lung	1.236	~0.2
F118	Kidney	1.859	~1.0
F118	Heart	1.883	~0.2



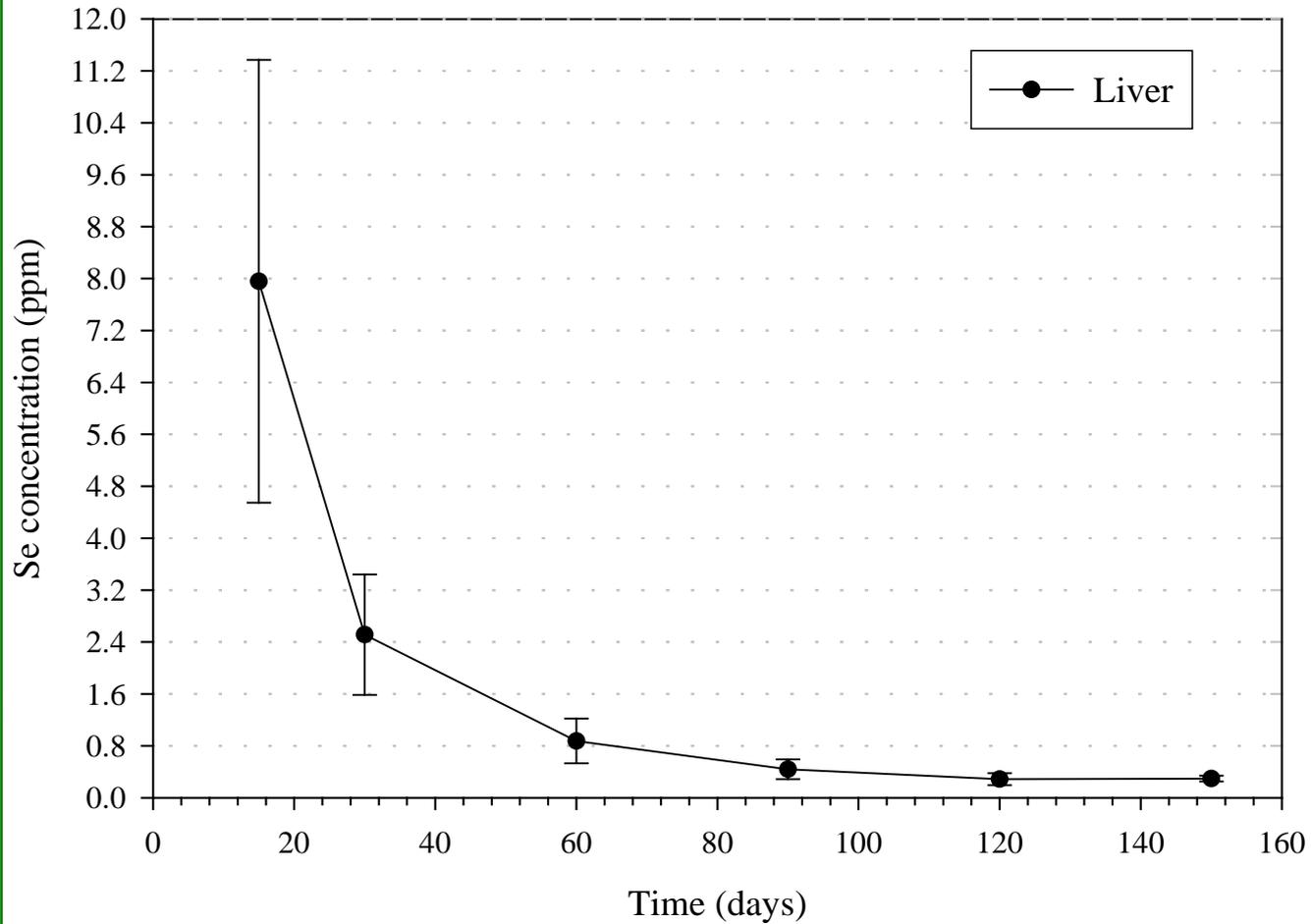


Average whole blood and serum selenium concentrations of steers poisoned on woody aster



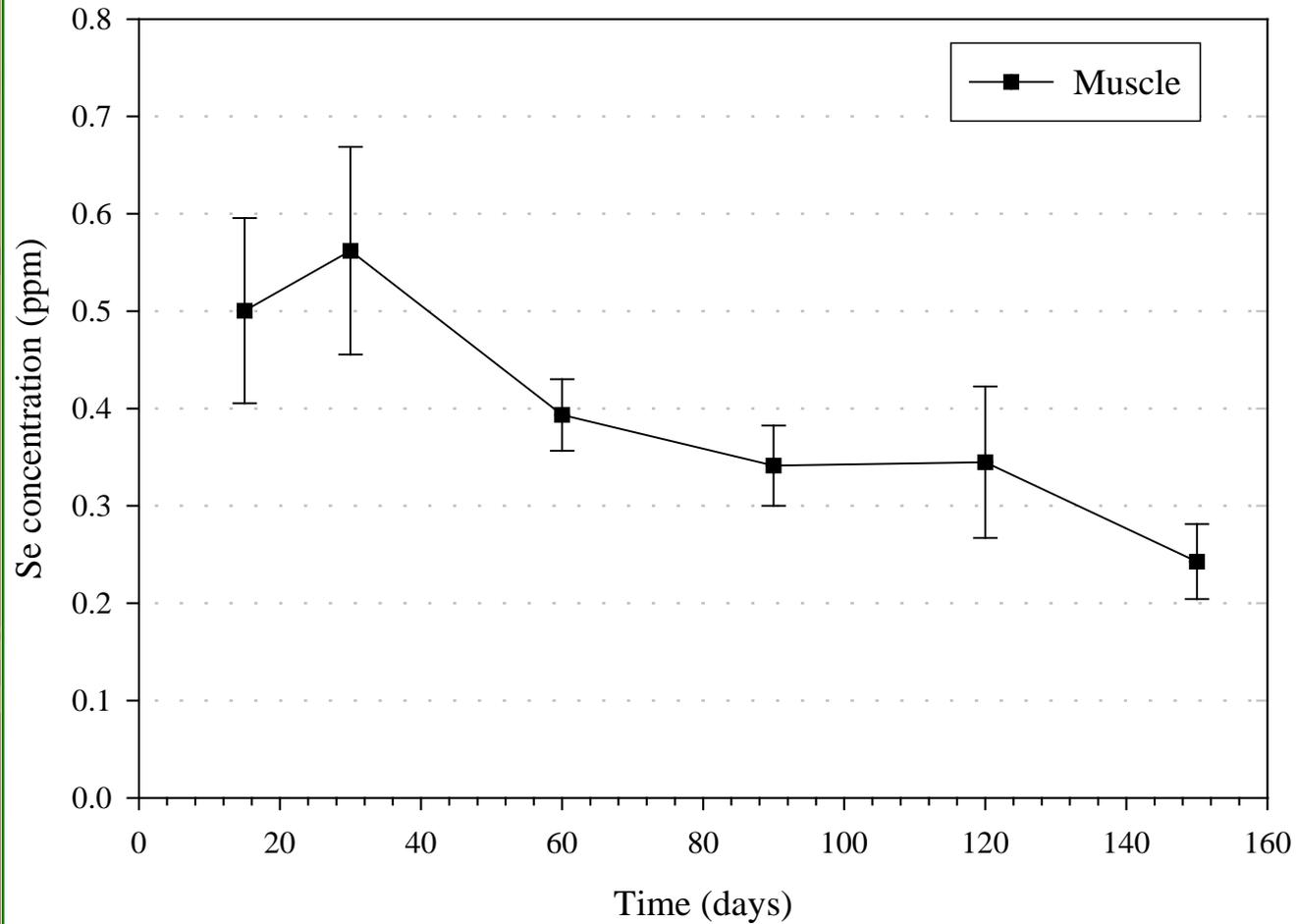
Normal range of selenium in bovine whole blood = 0.20 to 1.20 ppm
Normal range of selenium in bovine serum = 0.08 to 0.30 ppm

Average selenium concentration in liver of steers poisoned on woody aster



Normal range of selenium in bovine liver = 0.25 to 0.50 ppm

Average selenium concentration in muscle of steers poisoned on woody aster



Normal range of selenium in bovine muscle = 0.07 to 0.15 ppm

Questions

???????

Assigned Reading: pp 305-317 in A Guide to Plant
Poisoning of Animals in North America