Erionite: a Naturally-Occurring Fibrous Mineral Hazard in the Tri-State Area of ND, MT, and SD

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Background

- Erionite was identified in SW North Dakota by Forsman (1986)
- Erionite is a naturally occurring often acicular or fibrous zeolite mineral that pose an cancer risk from inhalation
- EPA 2006 Dunn Co. studies prompted evaluations in equivalent geologic units in the Tri-state area of NW South Dakota and SE Montana
- Documented erionite occurrences in other states AZ, CA, CO, ID, NM, NV, OR , UT, WY (R.A. Sheppard USGS 1996)

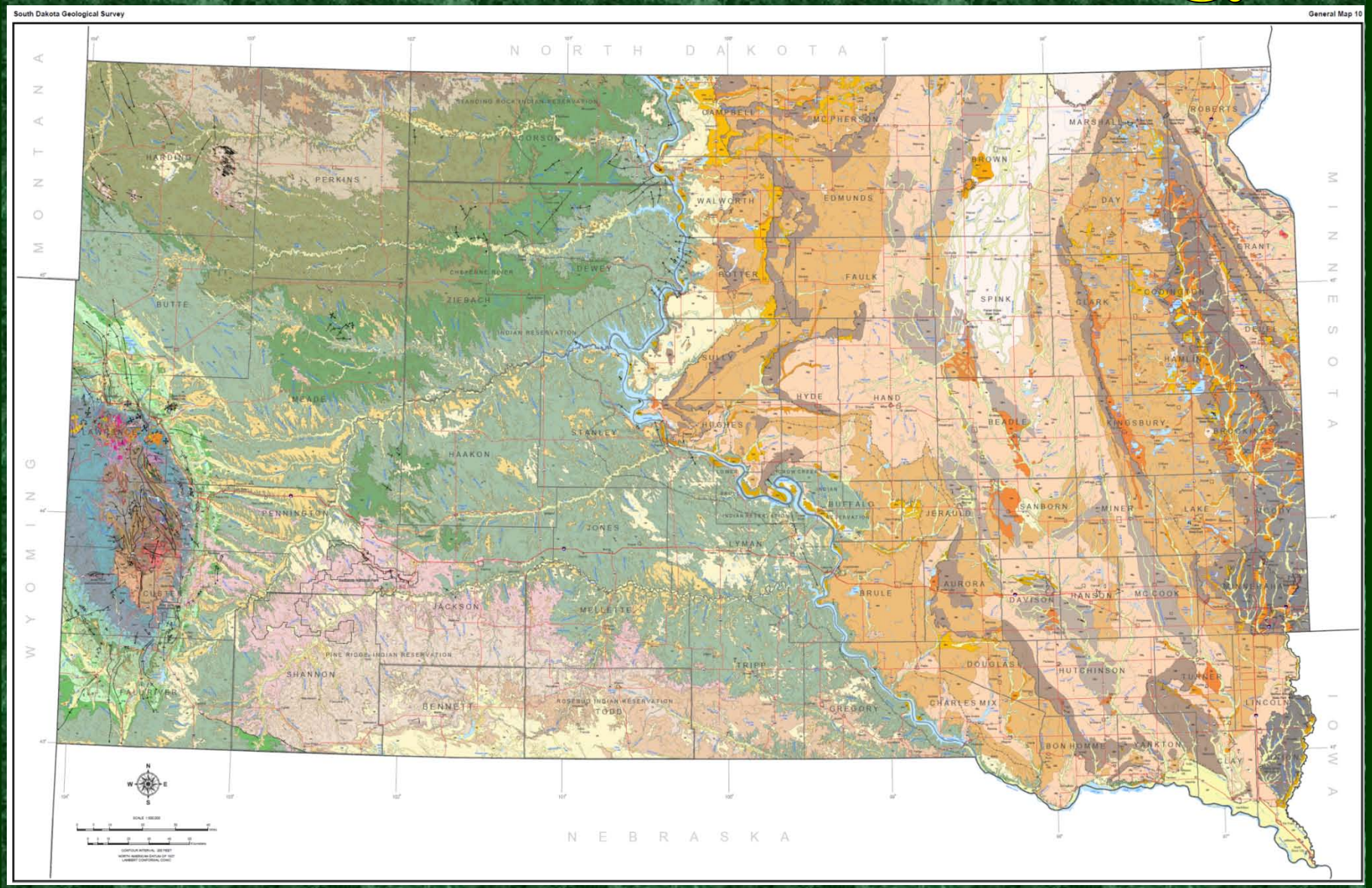
Tri-State Geologic Setting

- Erionite is associated with Tertiary “butte capping” formations mapped as the Arikaree and White River Formations including the Brule, and Chadron members within the Western Dakotas-SE Montana Region

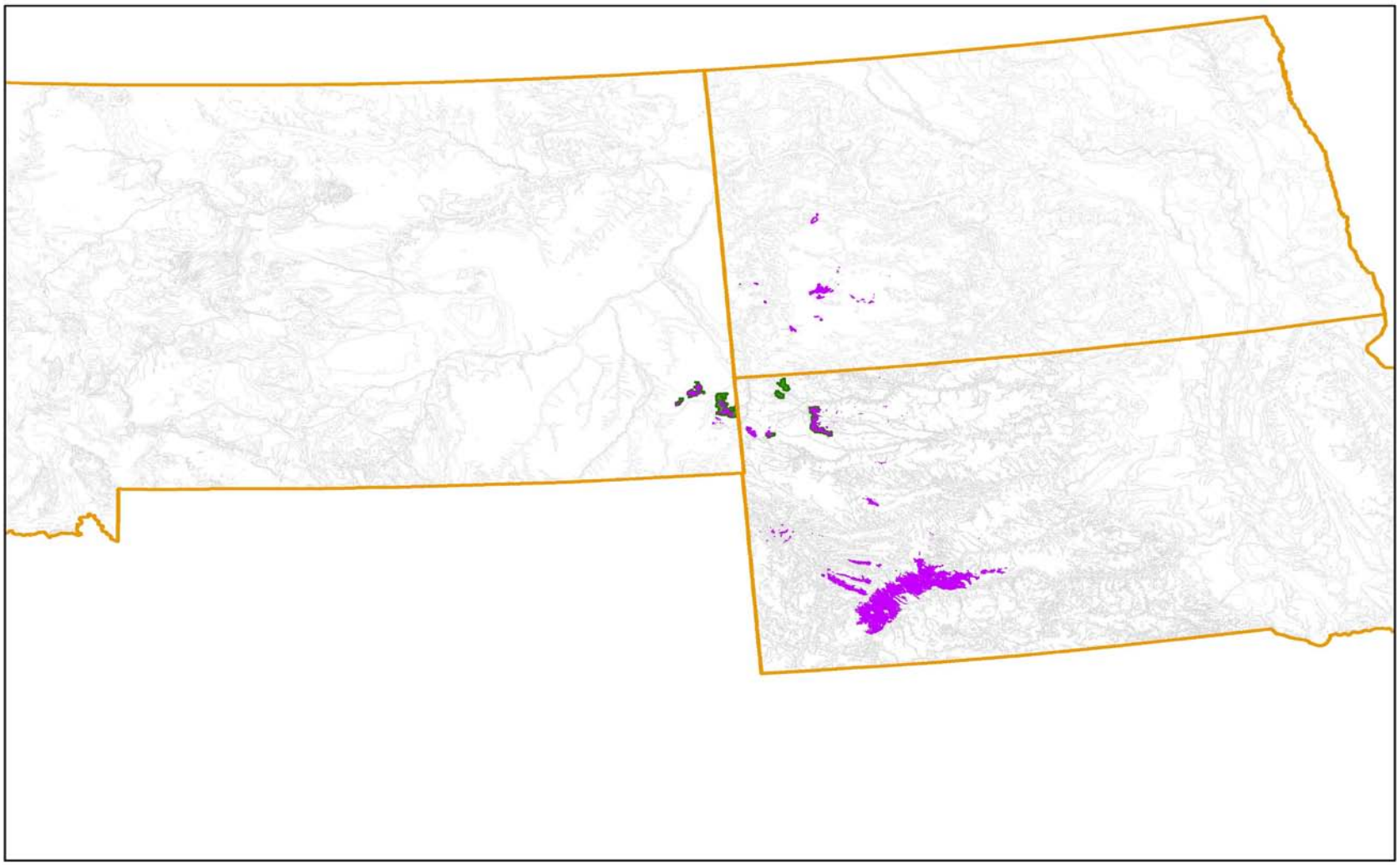
- Occurrence is primarily associated with dissolution of silicic ash fall tuffs followed by in situ re-crystallization

Typical Stratigraphy, CNF,Reva Gap SD

South Dakota Surface Geology



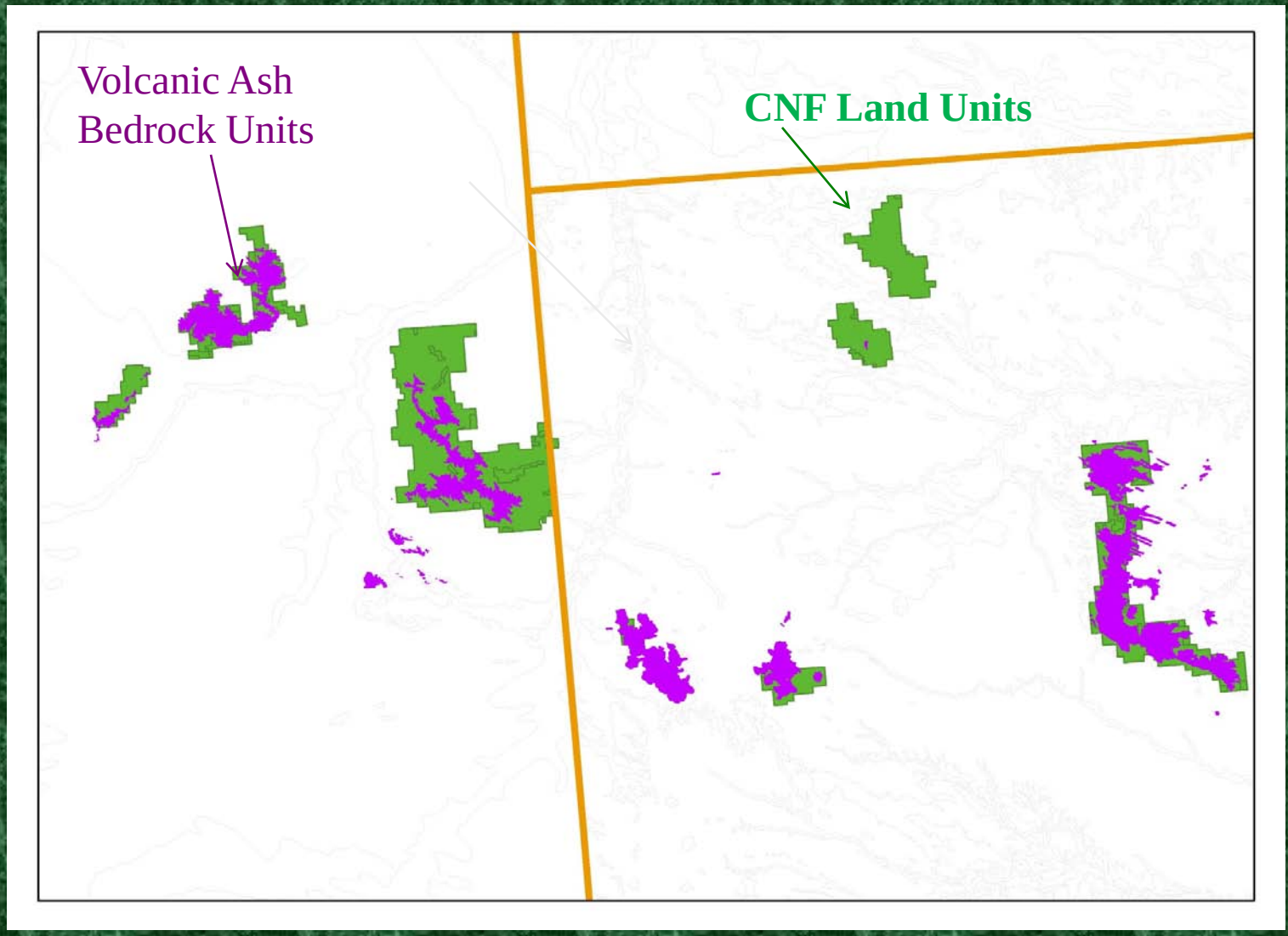
Arikaree and White River Group Regional Occurrence



Sioux District Erionite Coverage

- District consists of 176,716-ish acres
- 57,152 acres of Arikaree or White River bedrock occurrence (32% of Sioux District)
- Does not account for gravity (colluvium or surface water transport)
- Exact numbers of acres with erionite potential is unknown

Vicinity Map, Sioux District, CNF



CNF Management Actions to Date

- Sample collection and analysis across the Sioux Ranger District, CNF
- Sampling strategy focused on

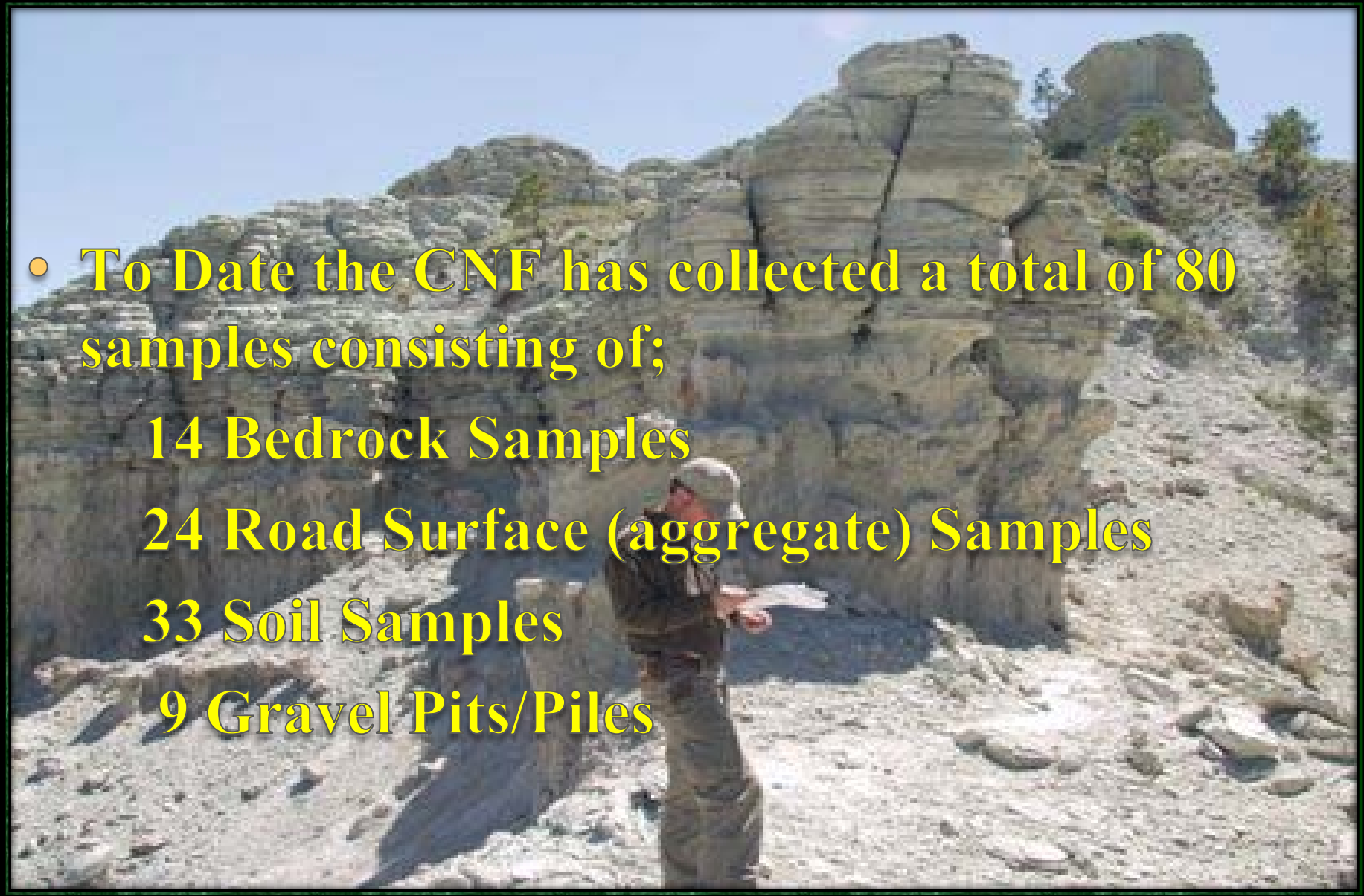
  - Occurrence (detect vs. non-detect)

  - % erionite composition by volume

  -Strategy also aimed at testing White River Group vs. Arikaree Fm.

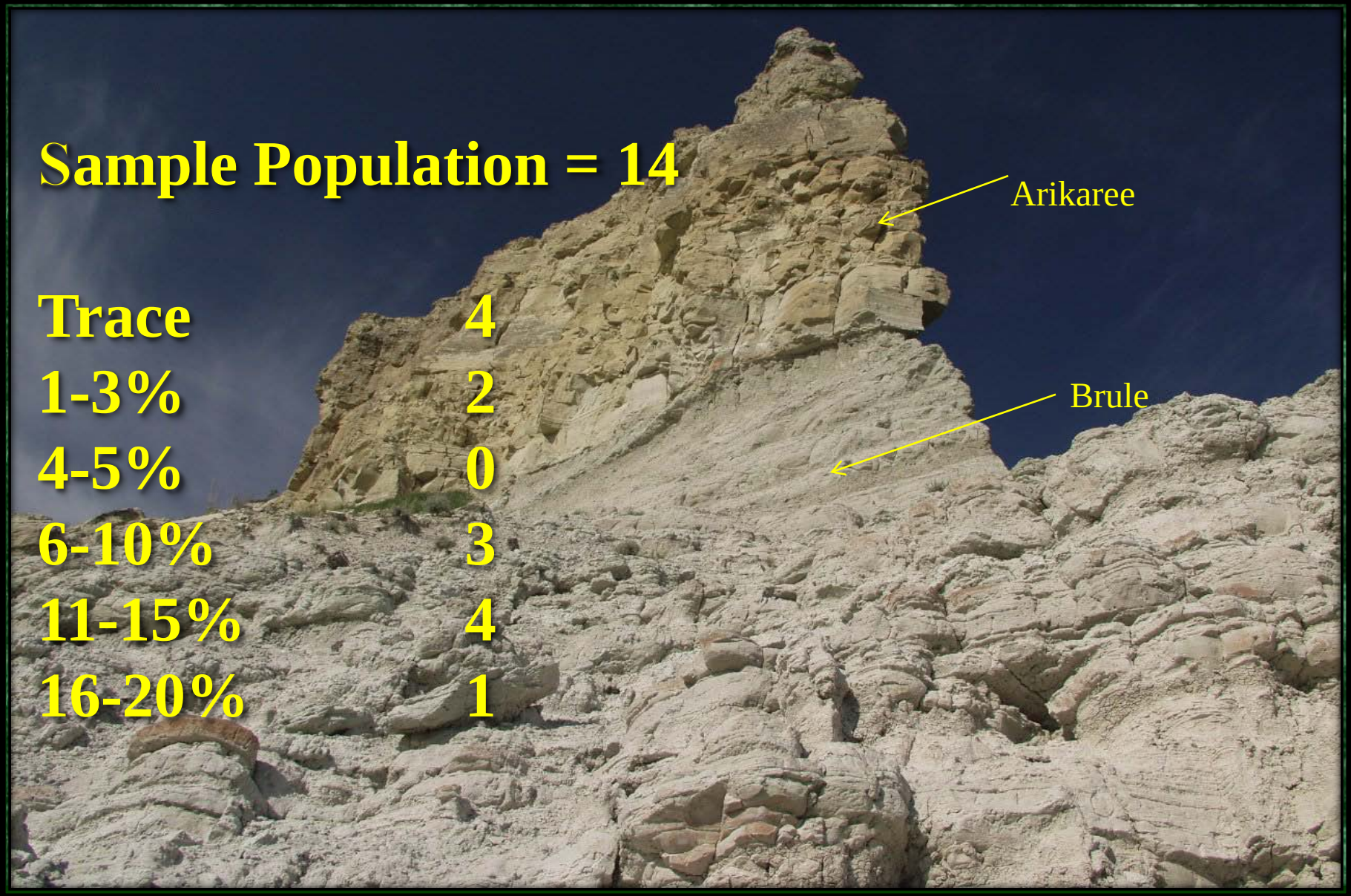
No attempt was undertaken to define if or where an erionite “enrichment zone” occurs

Data/Samples Collected



- To Date the CNF has collected a total of 80 samples consisting of;
  - 14 Bedrock Samples
  - 24 Road Surface (aggregate) Samples
  - 33 Soil Samples
  - 9 Gravel Pits/Piles

CNF Bedrock Samples Results



Spatial Variation of Erionite Content

CNF Soil Samples Results

Sample	
Population =	33
Non-Detect	0
Trace	12
1-3%	8
4-5%	8
6-10%	4
11-15%	1
16-20%	0

Erionite Sample Analyses Results

- Erionite concentrations vary within individual geologic units (Arikaree and White River including Brule and Chadron)
- Bedrock samples ranged from trace (<.025%) to 20% erionite by volume
- The Arikaree and Brule Formations appear to generally contains between 5% to 15% erionite
- Chadron Fm. appears to contain less erionite, may be related to bentonitic alteration
- Gravel Pits developed in Fort Union Formation contain non-detection to <1%

Erionite Chemistry

- Hexagonal cage-like structure of linked (Si, Al)O_4 tetrahedra
- Chain-like structure with 6 tetrahedra on each edge of a unit
- Absorbs up to 20% its weight in water

$$Ca_3K_2Na_2[Al_{10}Si_{26}O_{72}].30H_2O$$

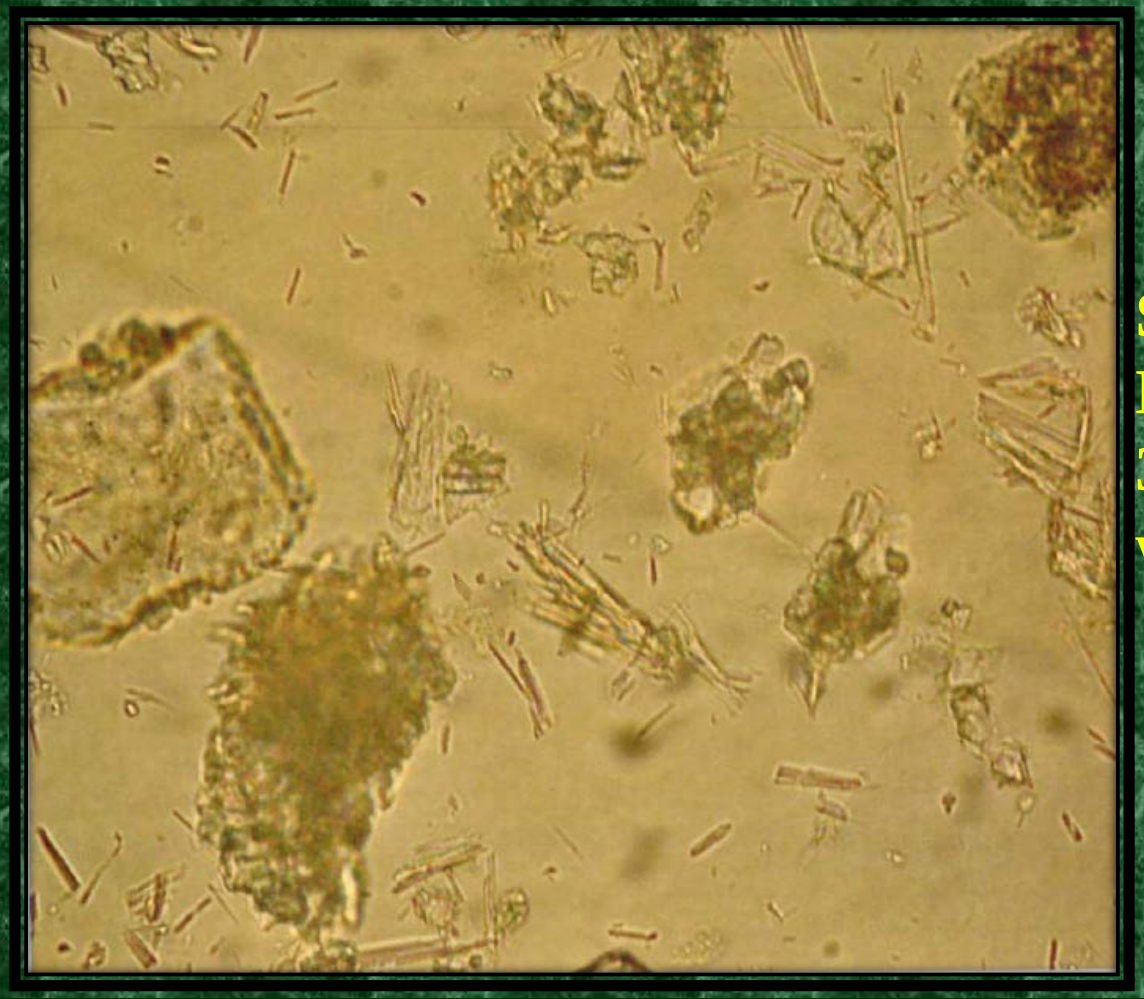
Erionite Mesothelioma Disease Clusters

- Erionite is considered a Class I carcinogen by the World Health Organization (WHO) and the International Agency for Research on Cancer (IARC)
- First mesothelioma disease cluster identified in the mid-1970s in villages in the Cappadocian region of Turkey, 50-60% death rate
- Recent mesothelioma disease cluster also identified in Zacatecas Mexico (Ilgren et al 2008)
- No erionite disease clusters indentified in the U.S., but have we looked hard enough?

Properties of Microscopic Mineral Fibers that Indicate Potential for Causing Asbestos-like Pathologies (after Cook EPA 2007)

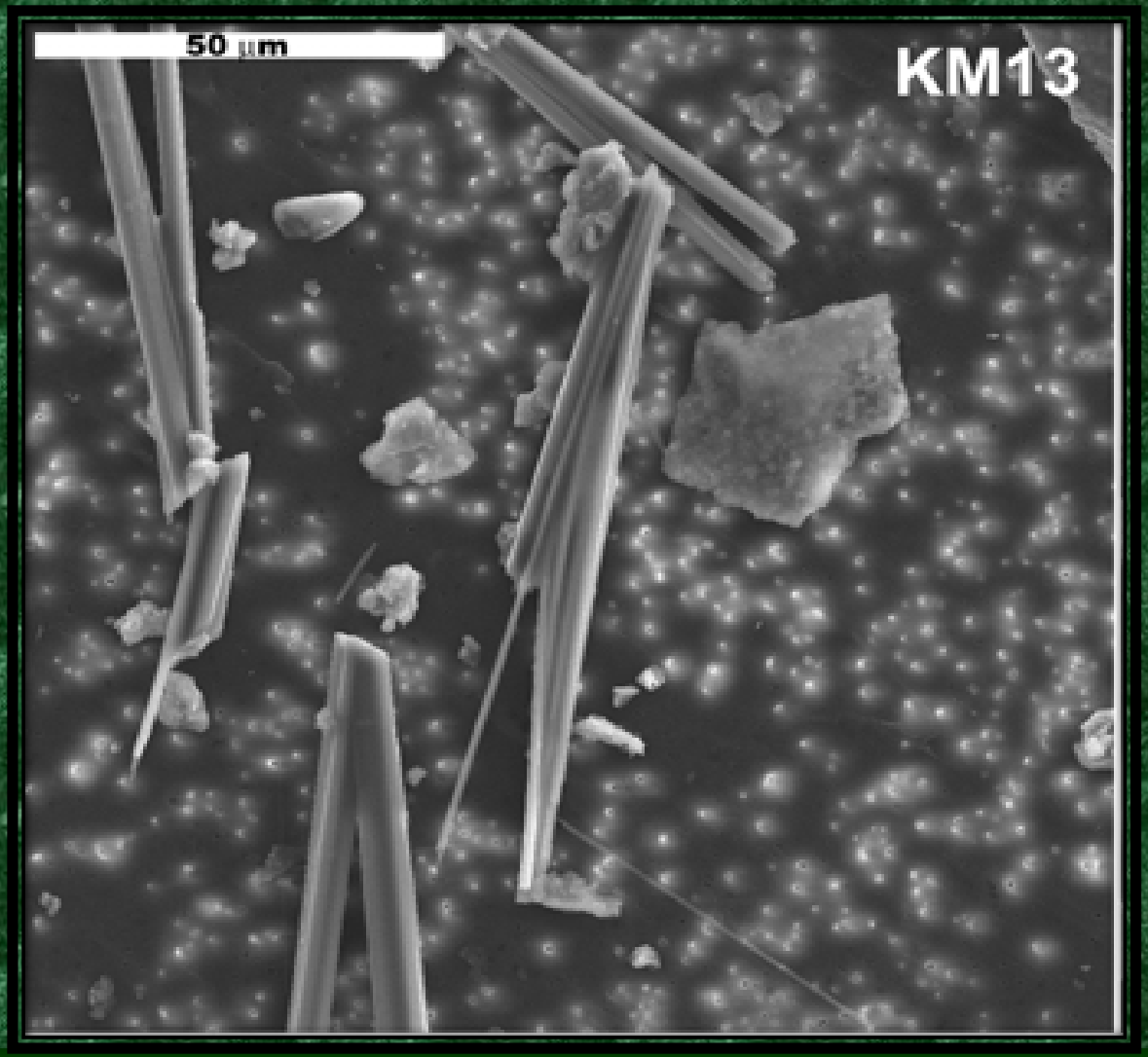
- Fiber size and shape that allows respiration (<1.5 microns), retention in lungs, and translocation to the pleural lining
- Durable, persistent in tissues
- Reactive surfaces (erionite is extremely adsorbent and hygroscopic)
- High collective surface area (erionite = 200 m^2/gram versus amphibole asbestos =15 m^2/g)
- Propensity to split into thin fibers *in vivo* (unknown)

Photomicrograph Arikaree Fm. Ekalaka Hills, Carter Co., MT



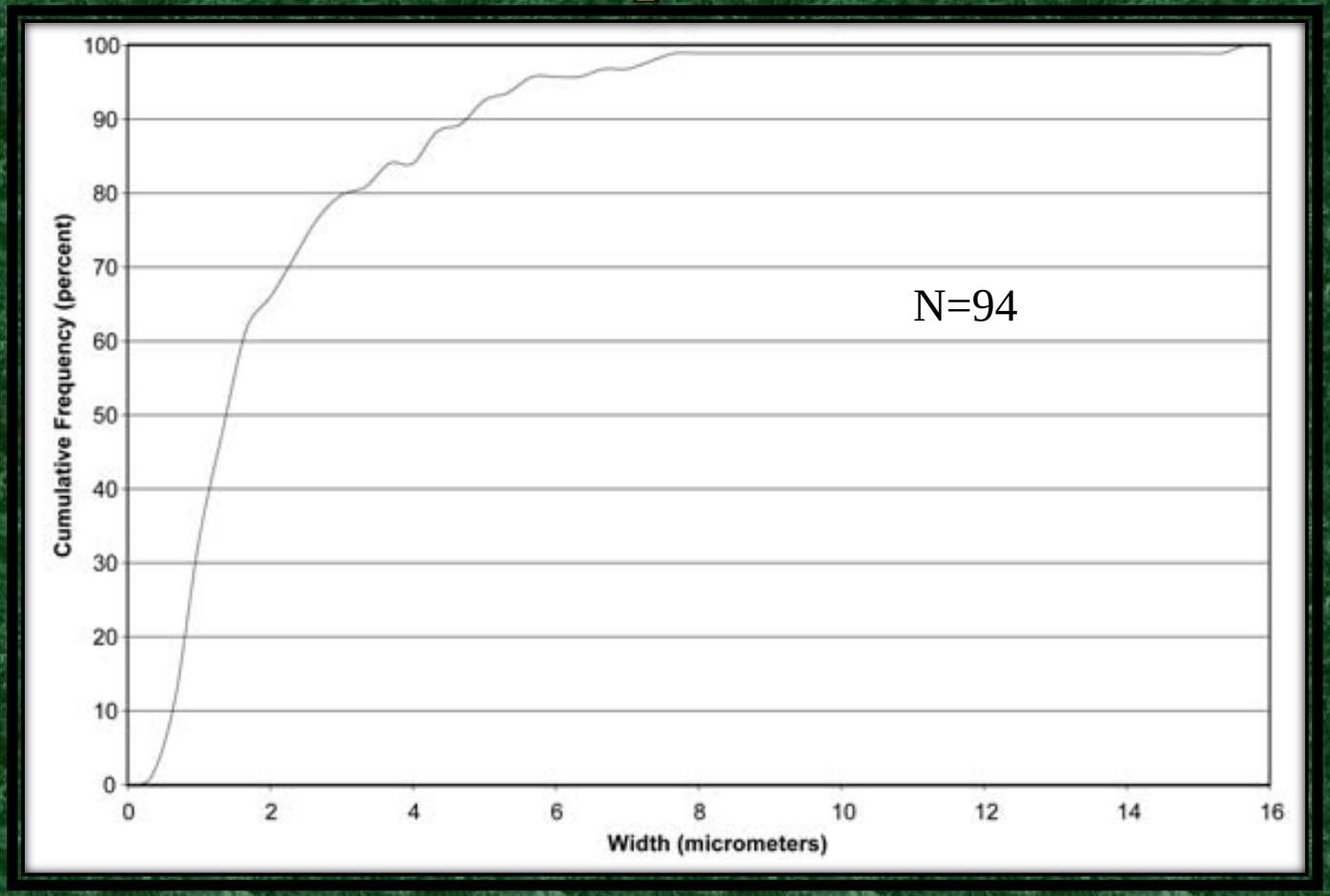
Source:
MDoT & EPA 2009
300 µm frame width

SEM Sample of Arikaree Fm. Dunn Co., ND



Source: USGS Lowers & Meeker 2007

Are there Respirable Erionite Fibers?



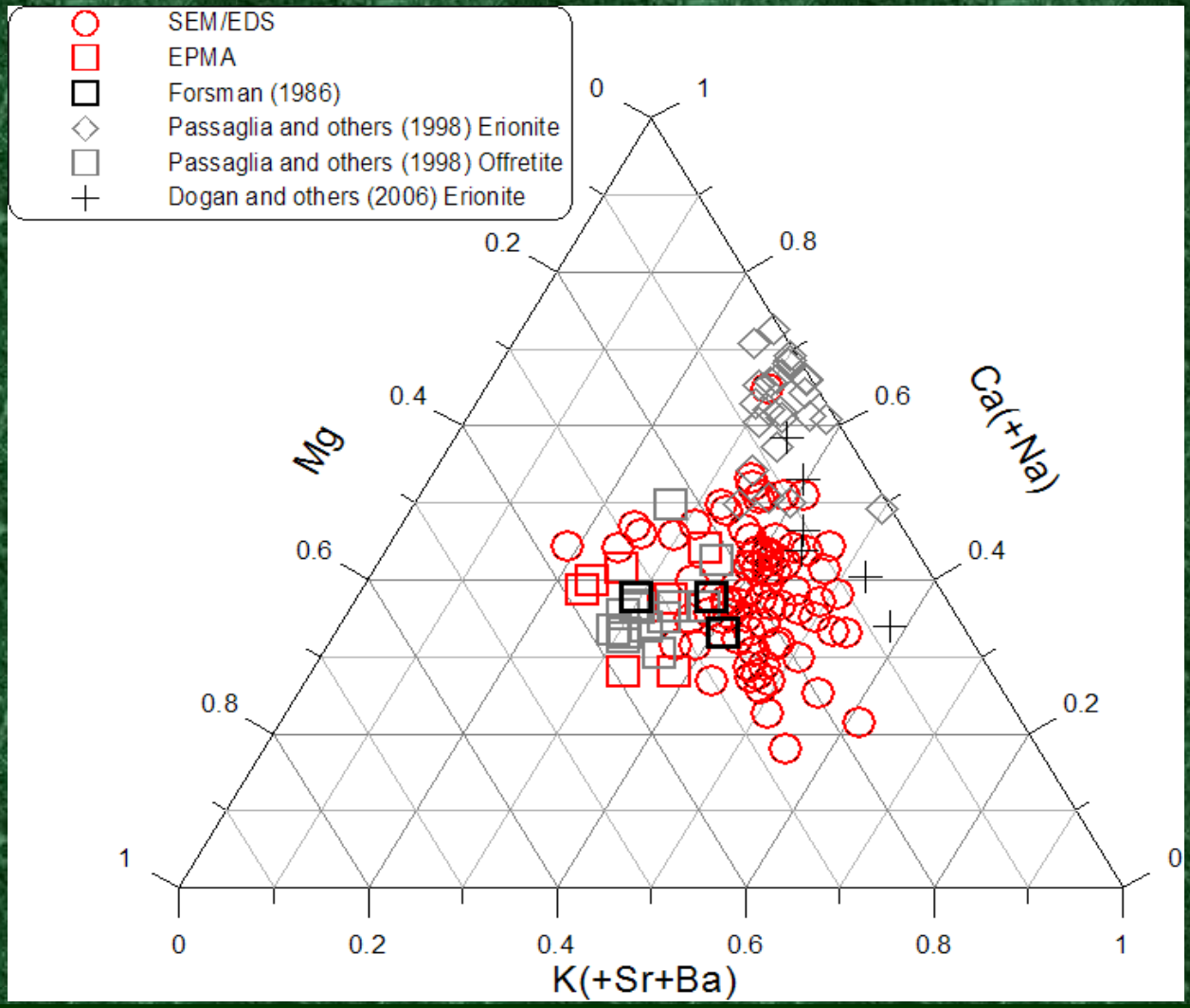
Source:
Dunn Co., ND
USGS
Lowers &
Meeker 2007

Yes - approx 40% were less than 1.5 microns

What is the Toxicity?

- Animal studies using Oregon and Turkish erionite intrapleural inoculation and inhalation produced very high cancer response rates –sometimes up to 100%
- Animal cancer response to erionite was much more rapid than with asbestos exposures and indicated substantially more carcinogenicity
- Was there genetic predisposition in Turkey or was it dose?

Does Erionite Cation Composition Matter ?



Source:
Lowers & Meeker
USGS 2007

Risk

- Fiber characteristics (respirable size)
- Level & duration of exposure (outdoor road dust, firewood harvesting, recreation)
- Time since first exposure (childhood exposure may be significant)
- Despite apparent toxicity, long latency still observed in Turkish populations
- Trace concentrations in samples still represent millions of fibers and an exposure hazard

U.S. Regulatory Status

- Currently, no exposure limits as with the six (6) regulated asbestos minerals
- Limited federal policy direction provided by EPA @ 40 CFR 721.2800
  - "A person who intends to manufacture, import, or process for commercial purposes ……and intends to distribute the substance must submit a significant new use notice."
  - "A significant new use is: Any Use"

2009 North Dakota Health Study

- EPA and North Dakota initiated a study to evaluate health consequences in the Dunn Co. area
- Sought 100 volunteers for testing
- Received approximately 35 volunteers to be tested
- Finding of Health study to be Released in June or July, 2010

CNF Management Actions

- Testing for Erionite presence prior to land management actions
- Use of Appropriate worker PPE such as Respirator, Tyvex, Gloves
- Prevent or Reduce Dust Generation
- Wetting ground disturbance during work
- Use of binder such as Magnesium Chloride
- Use of erionite non-detection aggregate sources

Montana DoT Management Actions

- Large mountaintop removal of Arikaree Fm. on MT Hwy S-323 occurred in the mid-1960s
- Erionite containing material was used over 3+ miles of highway project
- Maintenance worker protection measures are the same as used in Libby Asbestos NPL site including: Air purifying respirators, Tyvek suits and nitrile gloves, equipment decontamination , and HEPA vacuum equipment interiors

North Dakota Management Actions

- EPA studies initiated in 2006 to assess exposures in Dunn Co.
- Initiate health study to assess the health effects of erionite exposure in North Dakota
- ND DoT initiated special provisions on aggregate testing within estimated areas of erionite occurrence
- State has required increasingly stringent testing for erionite in other locations

Conclusions

- Erionite is present within the Tri-State area including large areas within the USFS Custer National Forest
- Erionite composition and “fiber” size are comparable to occurrences in mesothelioma cluster areas of Turkey
- No clear regulatory direction exists and further exemplifies the need for a national policy on naturally occurring asbestos (NOA) & erionite

Conclusions (Cont.)

- Erionite is NOT confined to the Tertiary ash-bearing units but also exist in the underlying Tertiary Fort Union and in eroded and transported sediments

- Take no land management actions which increases the exposure potential and protect workers performing maintenance and disturbance activities

Recommendations

- EPA initiate toxicity testing
- Conduct Activity Based Risk Assessment
- Develop Regulatory Framework