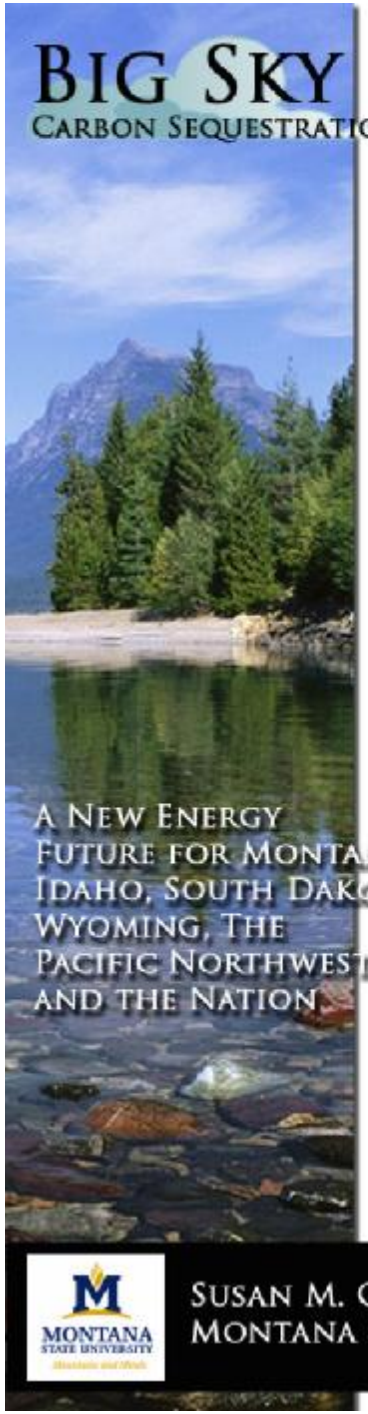


The Big Sky Carbon Sequestration Partnership

Susan M. Capalbo
Director
and
Professor, Ag Econ and Econ

October 19, 2005
Bozeman, MT

Outline

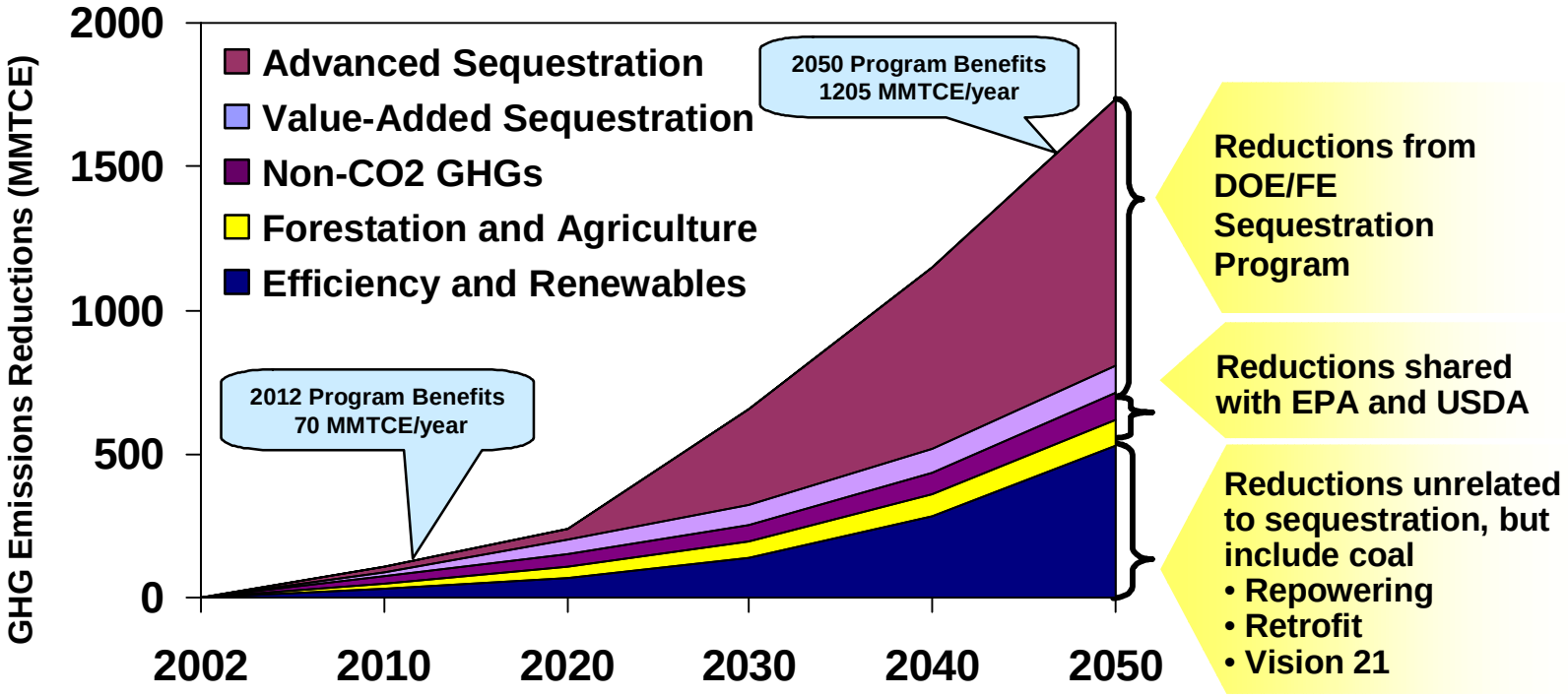
- Background on DOE Carbon Program and the Big Sky Partnership
- Geological and Terrestrial Sequestration
- Economic and Environmental Considerations

A Growing Case for Carbon Sequestration

- GCCI goal to lower GHG intensity
  - 18% improvement by 2012
- CO_2 Regulation at state, regional, National levels
  - Mandatory CO_2 requirements in MA, NH, OR
  - Other states and regions considering action
  - Recent legislation introduced by Sen. Hagel (3 bills, inc. S.388-voluntary) and Senator Byrd (S.745)
- Renewed emphasis on U.S. coal
  - Electric power generation
  - Feedstock for hydrogen economy
  - FutureGen
- Carbon Sequestration provides a means to achieve both energy security and environmental goals

Sequestration = Stabilization

Could Account for >60% of Reduction Gap in 2050



Sources: EIA Annual Energy Outlook 2002
EPA special studies
DOE/FE/NETL Sequestration Benefits Model

What is Carbon Sequestration?

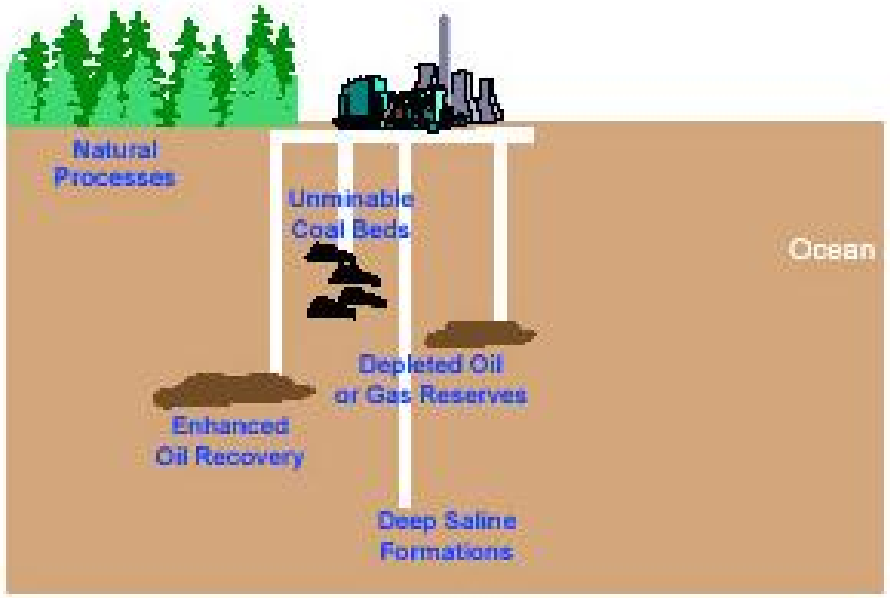
Capture and storage of CO_2 and other Greenhouse Gases that would otherwise be emitted to the atmosphere

Capture can occur:

- at the point of emission
- when absorbed from air

Storage locations include:

- underground reservoirs
- dissolved in deep oceans
- converted to solid material
- trees, grasses, soils, or algae

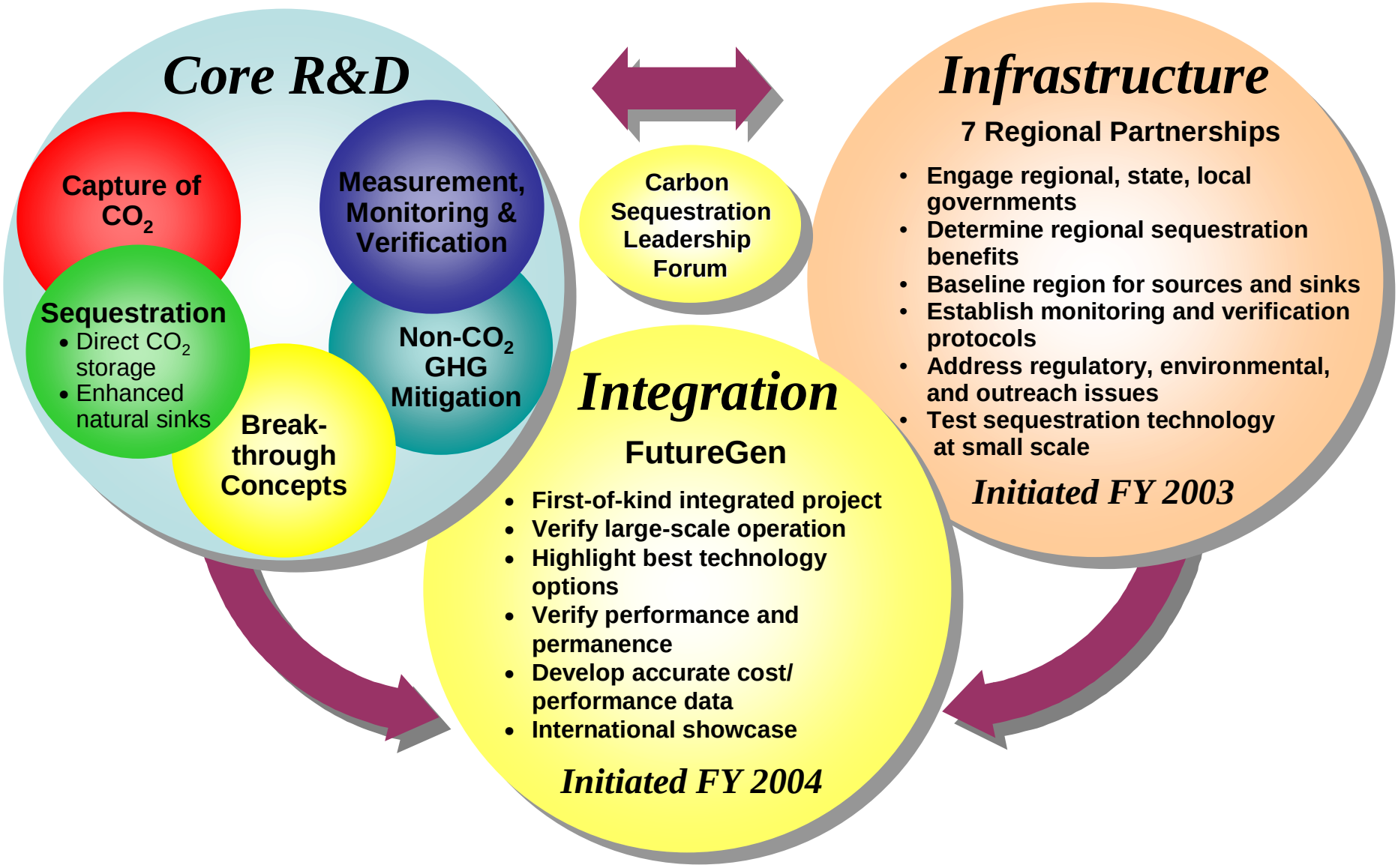


Successful Technologies to Sequester Carbon

Will need to:

- Be effective and cost-competitive
- Provide stable long-term storage
- Be environmentally benign
- Be acceptable to the public

Carbon Sequestration Program Structure



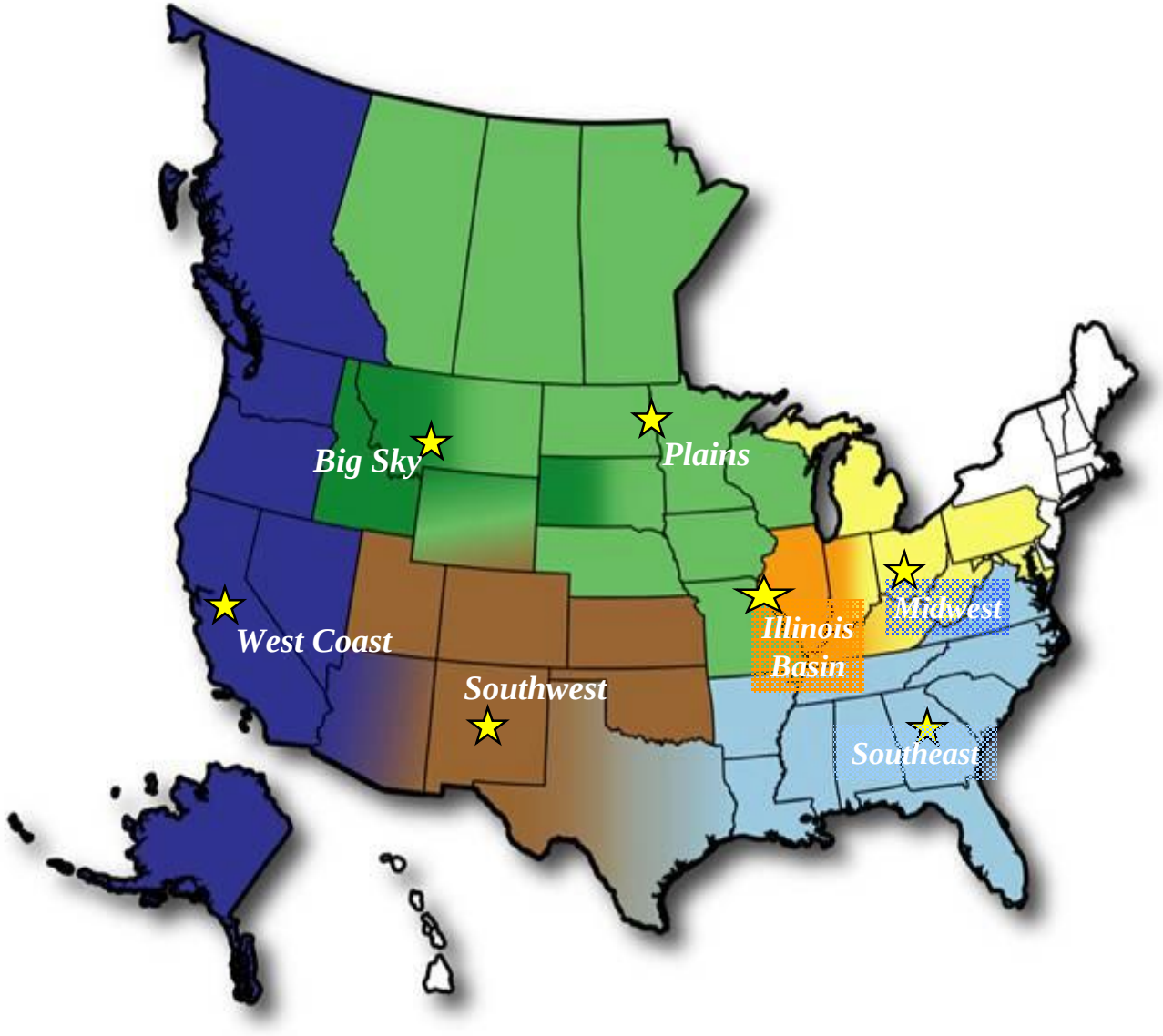
Regional Carbon Sequestration Partnerships

Developing Infrastructure for Wide-Scale Deployment

- Baseline region for sources and sinks
- Address regulatory, environmental, outreach issues
- Establish monitoring and verification protocols

- Determine benefits of sequestration to region

7 Regional Carbon Sequestration Partnerships



Overview of Big Sky Regional Partnership
www.bigskyco2.org

- Component of DOE's core program on CO_2 Capture and storage
- Partnership Goal: Develop infrastructure to support and enable future carbon sequestration field tests and deployment(regional orientation)
- Coalitions of professionals, and industry that represent regional interests and serve as driving force for carbon sequestration projects
- Phase I: 2003-2005 scoping/screening effort
- Phase II: Deployment of sequestration field validations and economic assessments of sequestration options

The Big Sky Partnership Region Contains Substantial Energy Resources

- Nearly 40% of total U.S. c**oal reserves** are in the Big Sky region
- Huge water resources to support **hydroelectric power**
- Many areas of high potential to support **wind power**
- **Natural gas reserves** may also be tapped in the future
- **Nuclear power** –part of the energy mix
- Canadian **heavy oils, tar sands**

Composition of Partnership

- Research Institutions (universities, labs, others)
  - Including MSU, UI, UWYO, ISU, PNWD/PNNL, LANL, INL
- State, federal agencies (includes USDA, USGS, NASA)
- Industry members including major power producers (Energy Northwest, Sempra Generation, Portland General Electric, Puget Sound Energy)
- Carbon trading entities (NCOC)
- Outreach Education partners, including Governors' office in WY, MT, WA
- Tribal Nations and Councils
- International Collaborators (includes Canada, Norway, India)

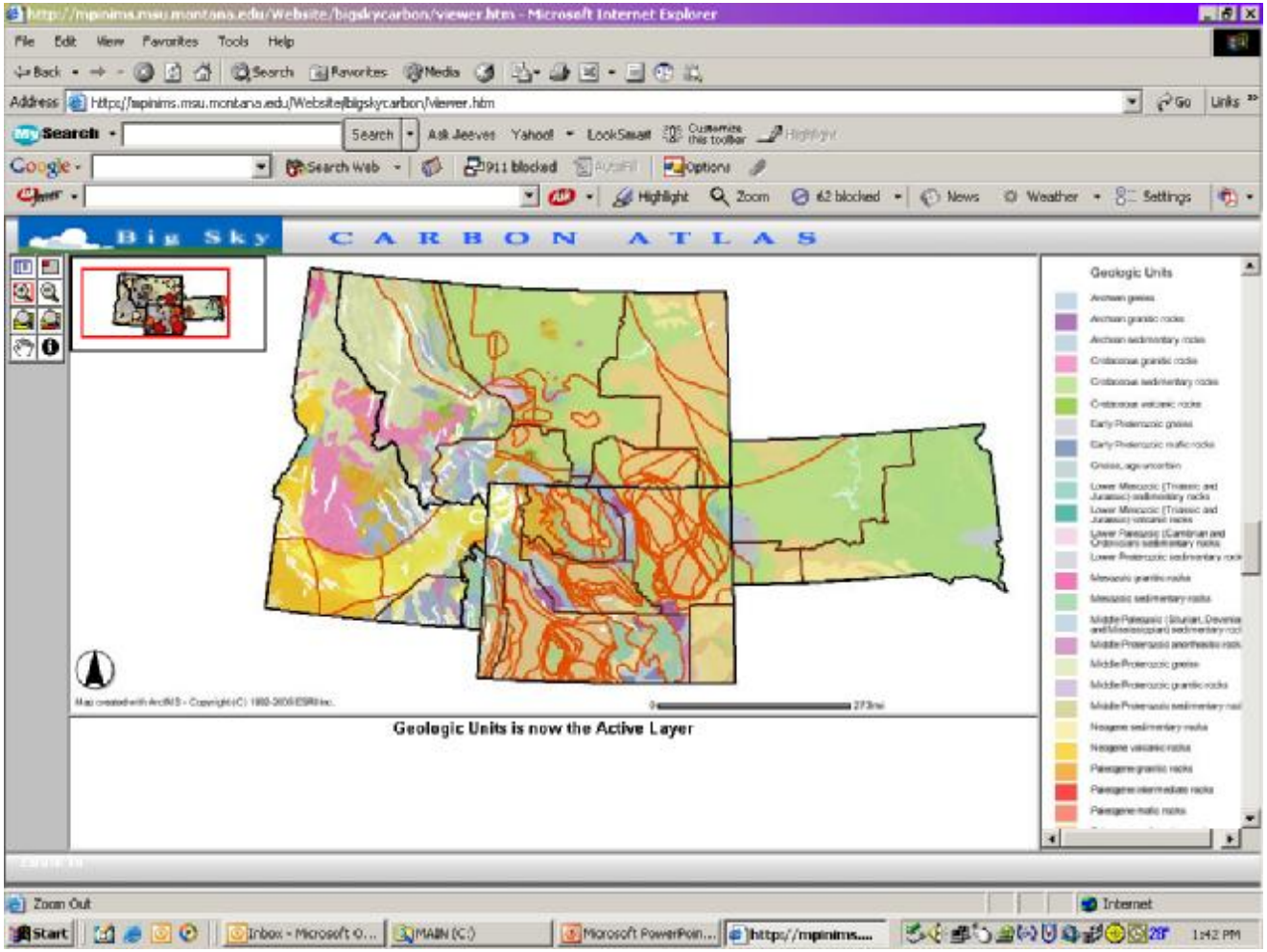
Partners

Battelle Pacific Northwest Division
Boise State University
Bullivant Houser Bailey PC
Center for Advanced Energy Studies at INL
Center for Energy & Economic Development
Clean Energy Systems
Columbia University, Lamont-Doherty Earth Observatory
Det Kongelige Olge - Og Energidepartement
Energy Northwest
EnTech Strategies, LLC
IBM
Idaho Carbon Sequestration Advisory Committee
Idaho Department of Administration
Idaho Department of Environmental Quality
Idaho National Laboratory
Idaho Soil Conservation Commission
Idaho State University
Inland Northwest Research Alliance
Institute for Energy Technology (Norway)
Institute de Physique du Globe de Paris (France)
Intertribal Timber Council
Jackson Hole Center for Global Affairs
Los Alamos National Laboratory
Montana Bureau of Mines and Geology
Montana Department of Agriculture
Montana Department of Environmental Quality
Montana Farm Bureau Federation
Montana Geographic Information Council
Montana Governor's Office
Montana State University
National Carbon Offset Coalition
National Geophysical Research Institute (India)
National Tribal Environmental Council
Nez Perce Tribe
Norwegian University of Science and Technology
Oregon State University
Portland General Electric
Power Procurement Group
Puget Sound Energy (PSE)
Ramgen Power Systems, Inc.
Research Council of Norway
Ruckelshaus Institute for Environment & Natural Resources (University of Wyoming)
Russian Academy of Sciences
Sampson Group
Semiarid Prairie Agricultural Research Center (Canada)
Sempra Generation
SINTEF Petroleum Research (Norway)
South Dakota School of Mines and Technology
Unifield Engineering
University of Idaho
University of Wyoming
University of Wyoming Enhanced Oil Recovery Institute
Wageningen University (The Netherlands)
Washington State Governor's Office
Western Governors' Association
Wyoming Carbon Sequestration Advisory Committee (University of Wyoming)
Wyoming Department of Environmental Quality
Wyoming State Governor's Office
Yellowstone Ecological Research Center

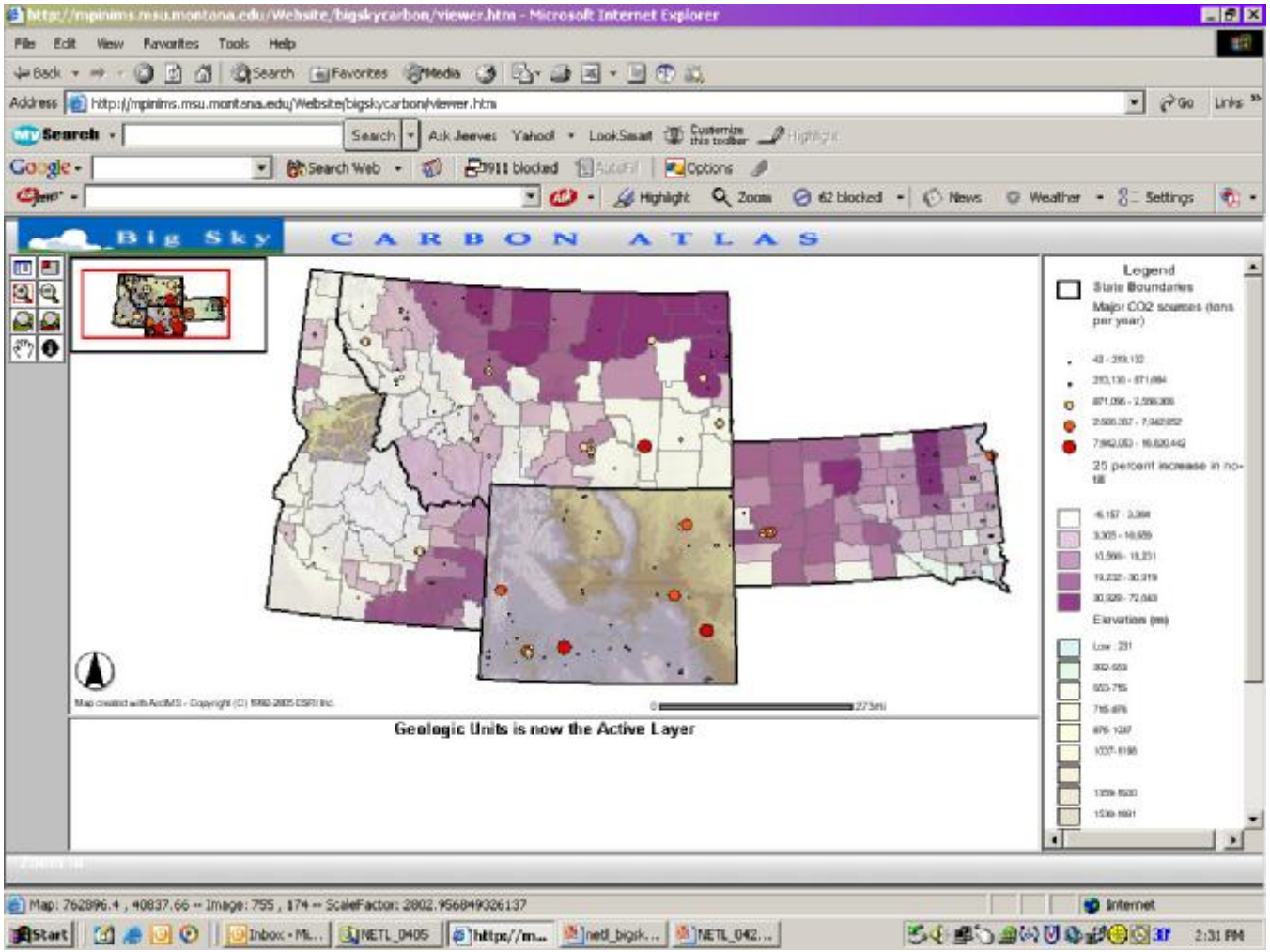
Phase I Experience

- Identify, assess and catalogue **sources of CO2 emissions** and promising **geological** and **terrestrial** sinks
- Develop an economic and risk assessment decision support framework to optimize region's C sequestration portfolio
- Carbon trading program – market-based storage methods and verification protocols
- Public education and outreach

Carbon Atlas: Geologic Sinks



Carbon Atlas: Terrestrial Sinks and Sources



Phase II and Beyond

- Utilize resource base to meet growing energy demand with portfolio of advanced technologies + sequestration opportunities
- Work with industry partners so that field test are effective, relevant to commercial development needs, and transferable
- Match storage capacity and storage integrity

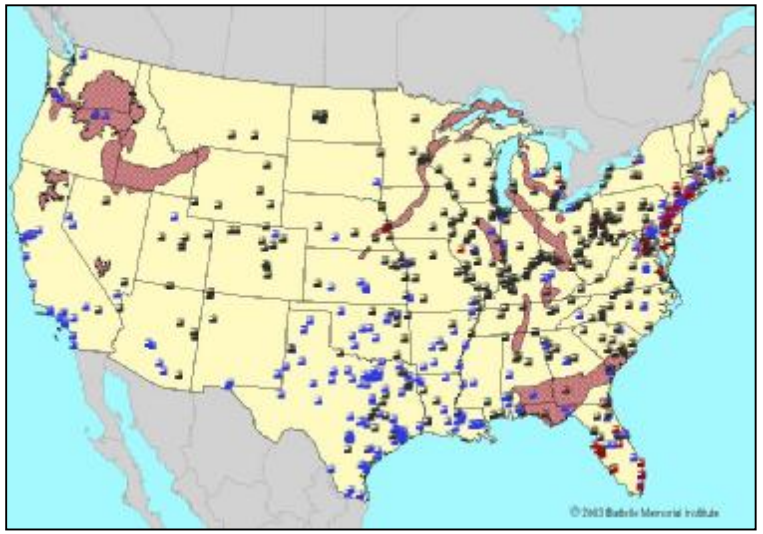
Phase II and Beyond (continued)

Geological Sequestration Efforts:

- **Demonstration projects**
  - **basalt pilot scale injection (form solid phase carbonates)**
  - **carbonate aquifer assessment (develop carbonate alkalinity)**
  - **deep coal bed exchange (separate and sequester from flue gasses)**
- **Transfer results to the Nation –**
  - **national mafic/basalt rock atlas**

CO_2 Sequestration in Basalts

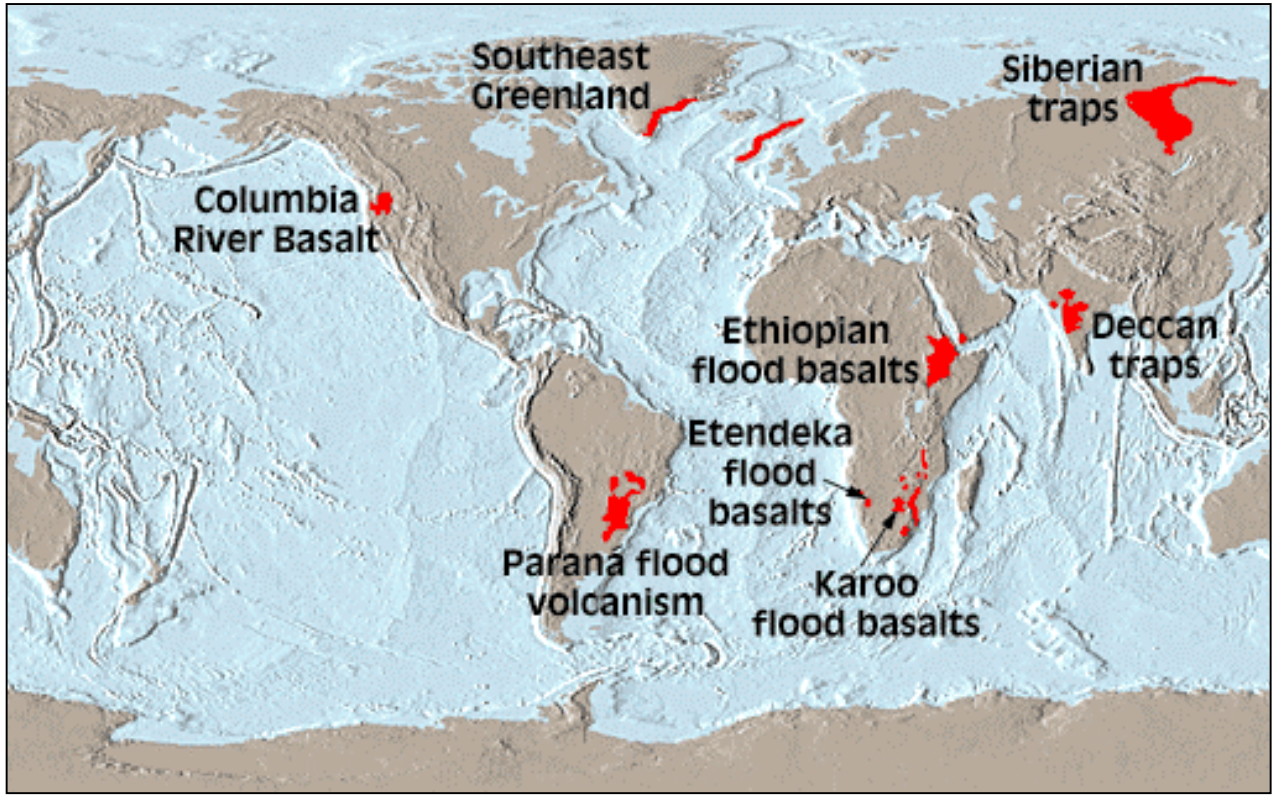
- Major flood basalt formations exist throughout the world
  - Important role in global carbon cycle
  - Implicated in past climate change events
  - Not widely considered as a geological sequestration option
- Build upon prior DOE investment in understanding basalt/aquifer systems that can be applied to carbon storage
- Capacity and Retention
  - Columbia River Basalt Group covers 164,000 km^2, >174,000 km^3
  - Chemical makeup favorable for mineralization reactions
  - Lateral connectivity of interflow zones but limited vertical connectivity between flows
- Water Resource Implications
  - Upper aquifers (<300 m) are major source of water
  - Deeper aquifers contain non-potable water



Columbia River Basin: Sequestration Example

- 164,000 km^2 of the Pacific Northwest
- 15% porosity
- 10 interflow zones
- Hydrostatic pressure 100 atmospheres
- Storage capacity of more than 100 Gt
- 100 years of U.S. Carbon emissions

Flood Basalts Cover More Than 1 Million km² of the Earth's Surface



Conclusions

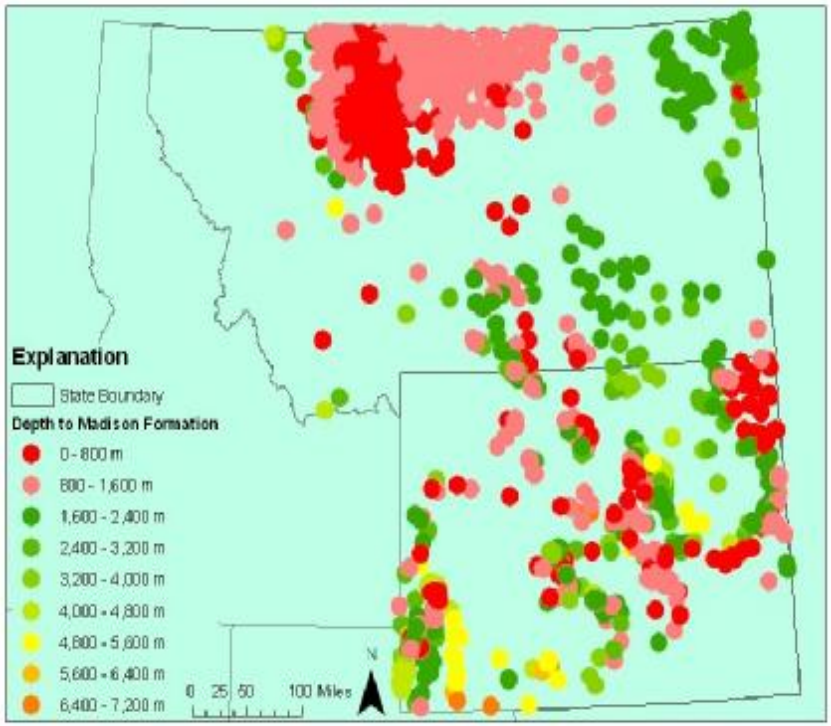
- Large basalts providences globally distributed
- No significant economic opportunity costs of injection
- Conducive mineralogy for sequestration
- Rapid conversion of CO_2 to carbonate
- High porosity and permeability
- Five largest basalt provinces could sequester 10,000 years of world CO_2
- Big question: how does this compare to costs of other sequestration options and other mitigation options – topic for another presentation!

Carbonate Petroleum Reservoir Pilot

- Regionally abundant carbonate rocks (dolomites and limestones) are highly reactive with CO_2

$$CaMg[CO_3]_2 + 2CO_2 + 2H_2O \rightarrow Ca^{2+} + Mg^{2+} + 4HCO_3^-$$

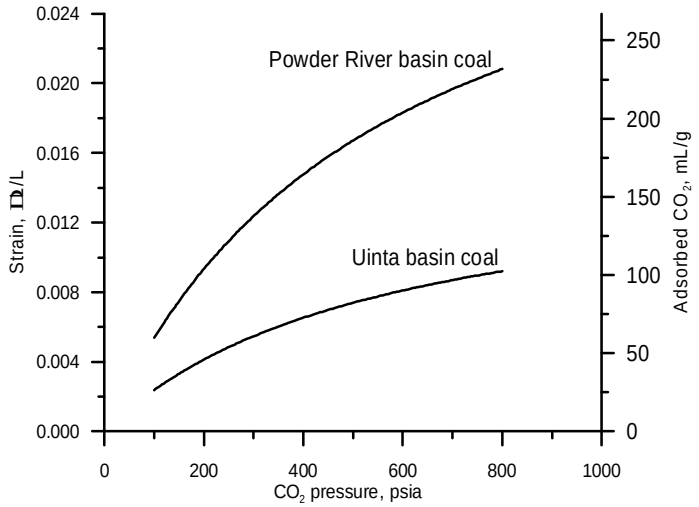
- Reactions should result in permeability and porosity increases

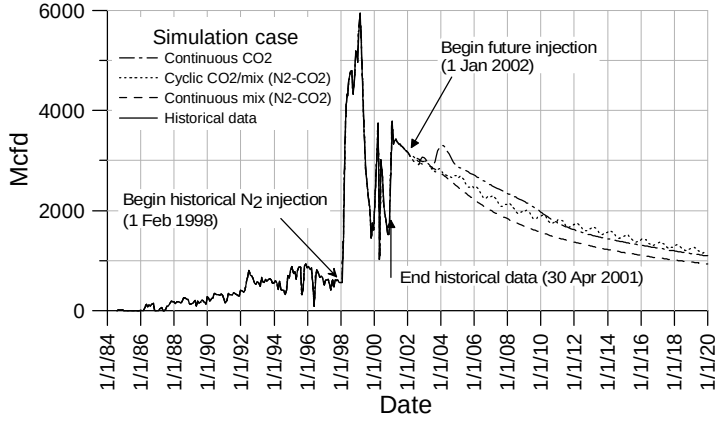


Depth to Top of Madison Formation

Enhanced Coal Bed Sequestration

- Recent work shows Powder River basin coals can adsorb twice as much CO_2 as Uinta basin coals
- Study various gas injection strategies
  - Economic evaluation
  - Reservoir simulation
- Attention will be given to impact of coal swelling on permeability changes





Phase II and Beyond (continued)

Terrestrial Sequestration Efforts:

- **Advance Phase I market-based storage and verification protocols -- NCOC**
- **Cropland, forestland and rangeland field test sites and carbon portfolios in conjunction with industry, tribal members, and landowners**

Terrestrial Pilot Projects

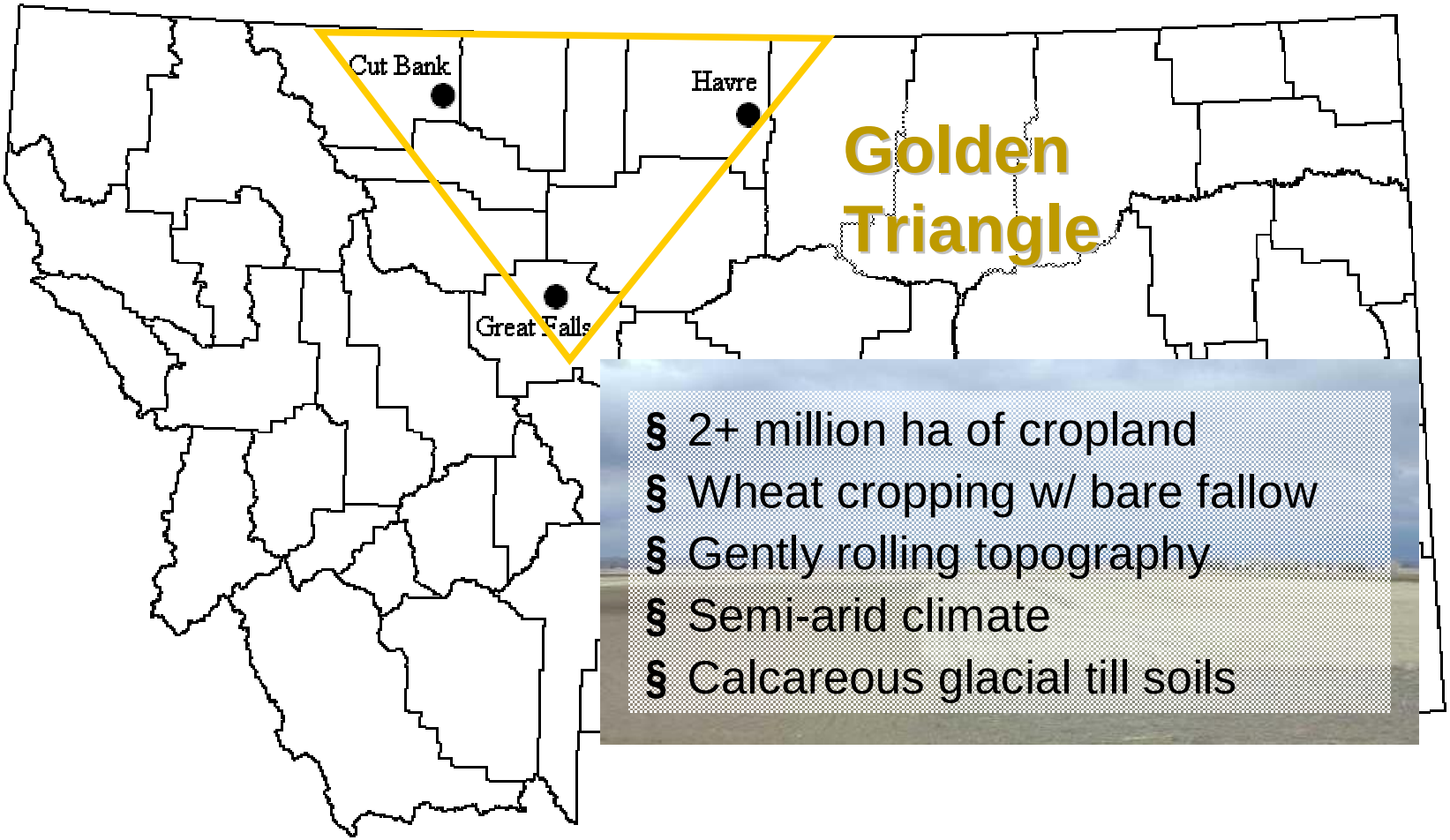
- § Forestry
- § South Dakota web-based enrollment
- § Wyoming Rangeland (U of Wyoming)
- § North Central Montana Cropland
  - Private lands (Big Sky)
  - Tribal lands (Big Sky + national)
  - Year 4: remote sensing MMV
  - No-till cropland, CRP, rangeland
  - Monitoring soil & biomass C in existing range management studies.
  - Sampling costs and information gains from spatial-temporal sampling designs

South Dakota School of Mines and Technology

Institute of Atmospheric Sciences

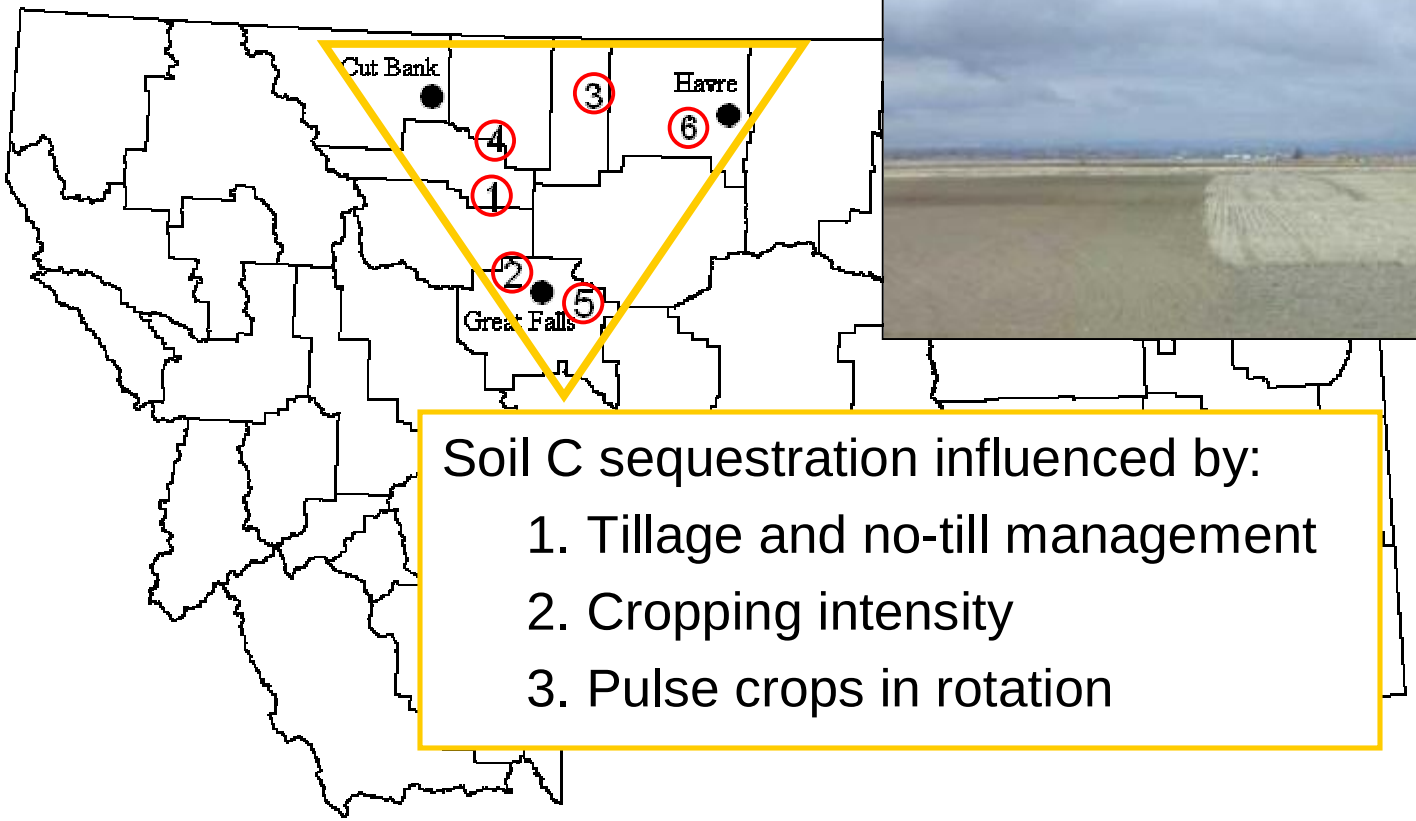
Ted Dodge & Neil
Jerry Schuman & George Vance
National Carbon Offset Coalition
University of Wyoming

North Central Montana Cropland



- 2+ million ha of cropland
- Wheat cropping w/ bare fallow
- Gently rolling topography
- Semi-arid climate
- Calcareous glacial till soils

North Central Montana Cropland

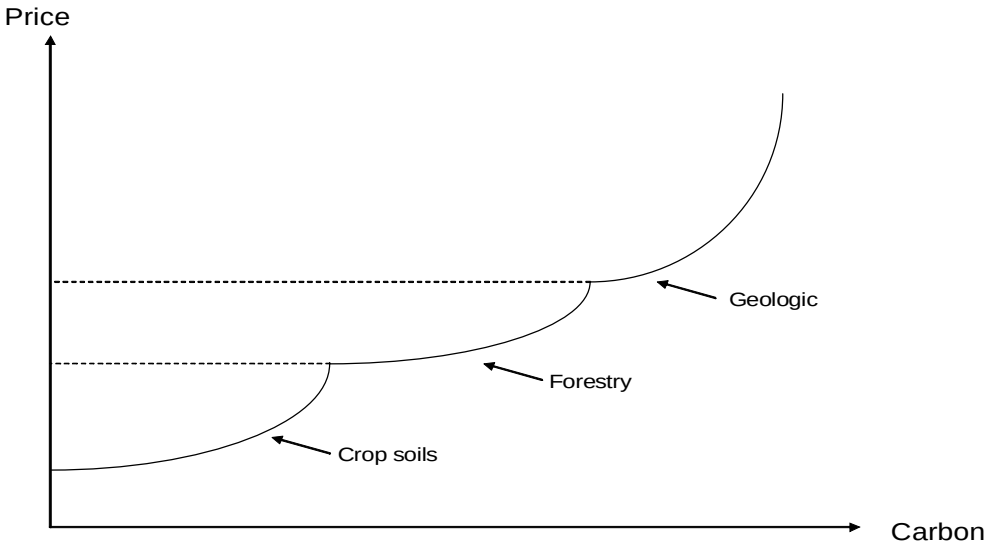


Soil C sequestration influenced by:

1. Tillage and no-till management
2. Cropping intensity
3. Pulse crops in rotation

Integration Activities: Economic Analysis

- Economic potential for geologic and terrestrial sequestration
- Quantify regional carbon supply curves
- Potential for large
  - scale deployment



Why Is This Important?

- Critical to addressing the feasibility of scaling up of the sequestration activities
- Useful for addressing long term financial viability of power plants under carbon-constrained scenarios
- Used to address tradeoffs among alternative sequestration options

Integration Activities: Public Outreach and Education

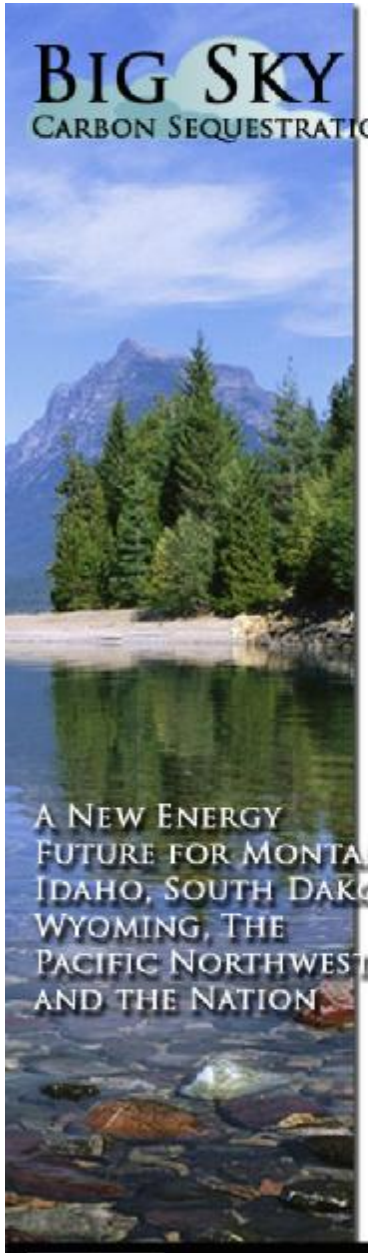
- Build public acceptance and support
- Ensure field validation permitting requirements are met
- Pursue practical coalition building
- Highlight results

Webpage Highlights:
www.bigskyco2.org

- Carbon Atlas
- Primary Source Emissions Statistics
- Partnership Publications/ Presentations/Reports
- Partnership Management/Key Contacts/Technical Leads
- Terrestrial, Geologic and GIS Links, Educational Material

Public Outreach & Education: Activities

- Annual Energy Forum & Report
- Energy Future Coalition
- State Legislative Symposia
- Partnership Recognition/Media Network
- National Outreach Working Group
- Capacity Building



Contacts:

Susan M. Capalbo
Montana State University
scapalbo@montana.edu

Big Sky Partnership Office
Angie Solvie
asolvie@montana.edu
Office: 406-994-3755