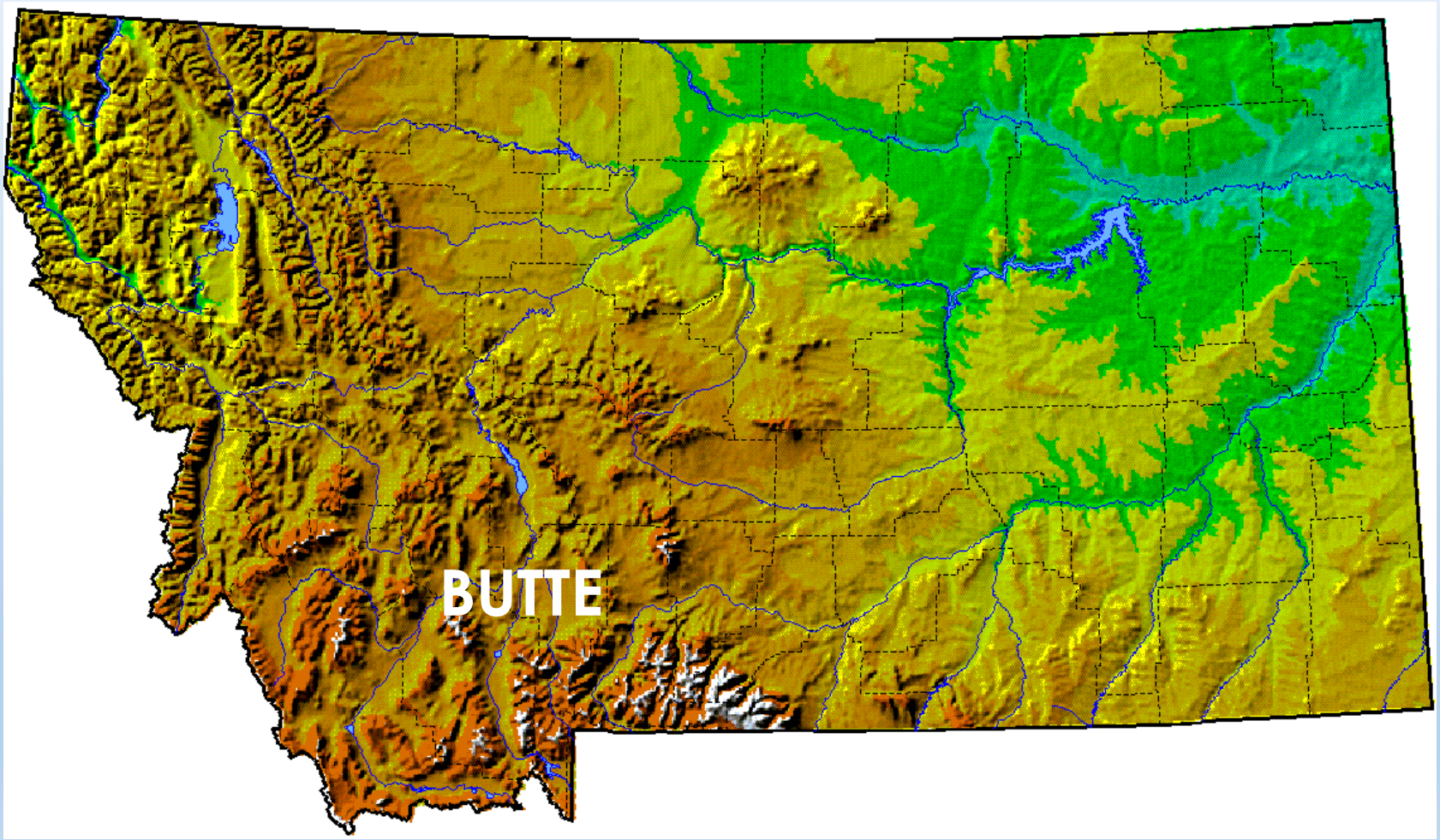
Montana Tech

Inaugural Meeting of the National Energetic Materials Consortium

R. J. White
Director, Center for Advanced
Mineral & Metallurgical Processing

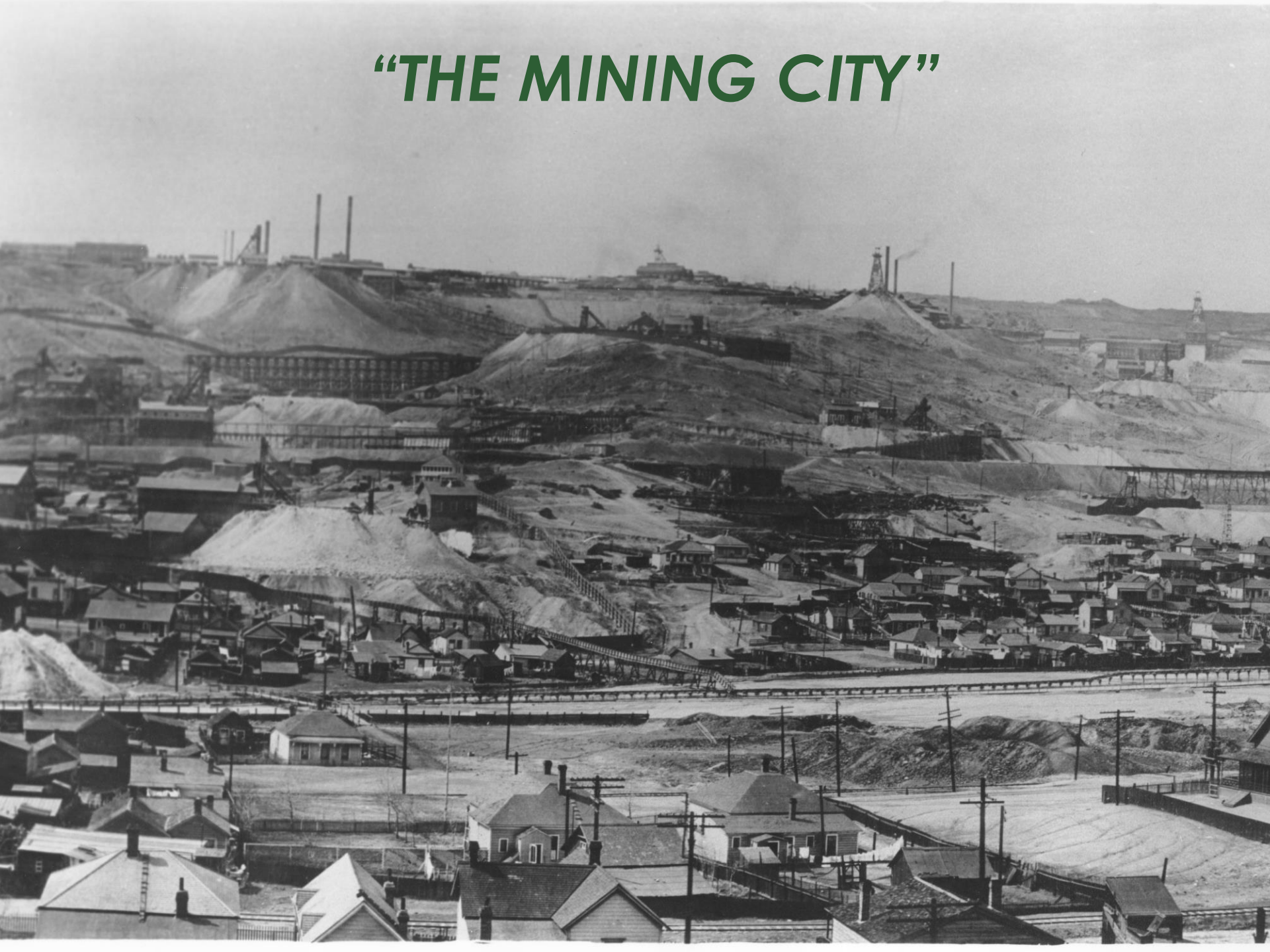
October 13, 2015

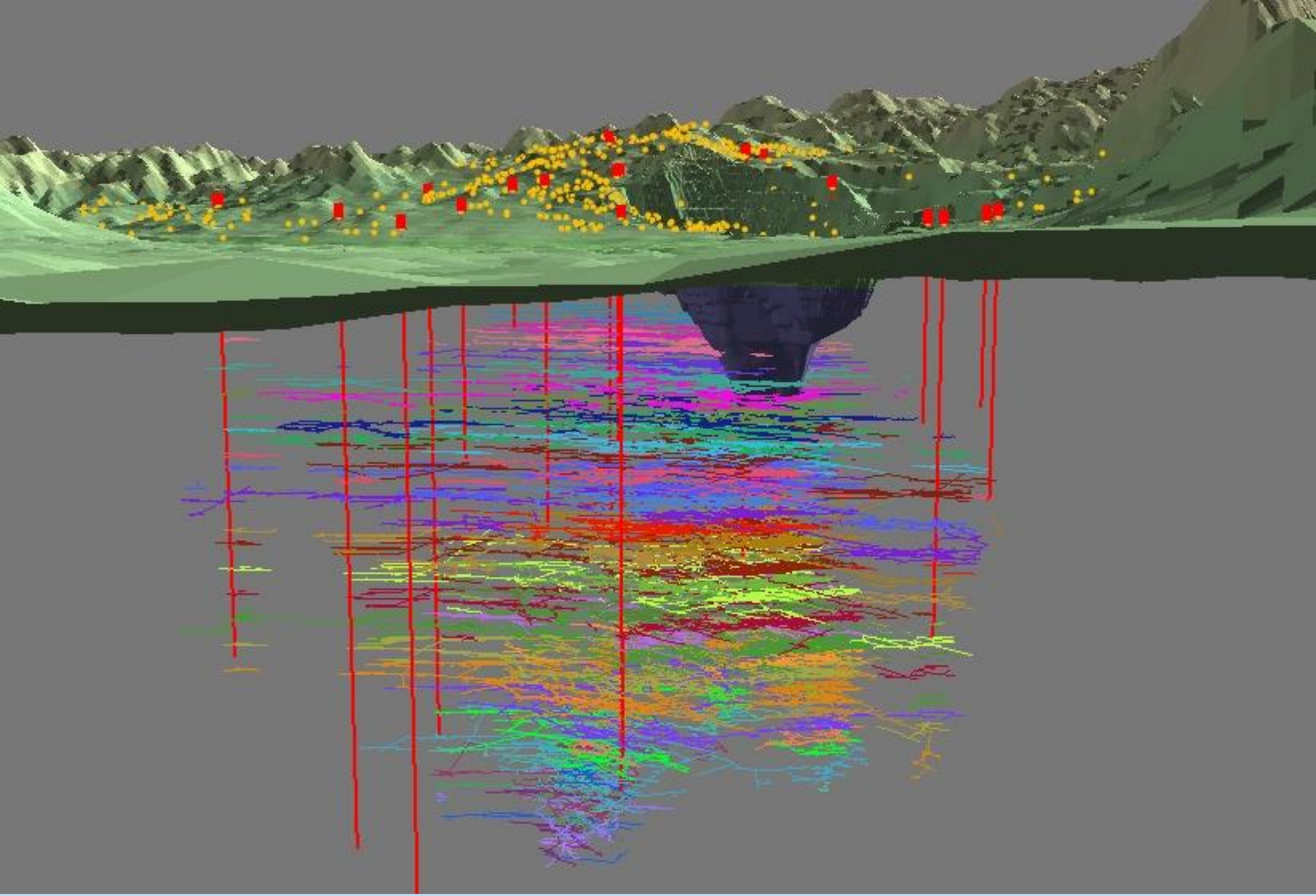
STATE OF MONTANA



BUTTE, MONTANA

“THE MINING CITY”





MONTANA TECH

OUR CAMPUS COMMUNITY

2,980 students from

20 countries

210 graduate students

228 Faculty (75% with Doctorate)

312 Staff

RESEARCH INFRASTRUCTURE

STATE RESEARCH CENTERS

- **Center for Advanced Mineral & Metallurgical Processing (CAMP)**
  - Complete suite of metallurgical & mineral processing facilities
  - Characterization, analysis, added-value processing of minerals, metals & other materials; minimization of waste streams
- **Montana Bureau of Mines & Geology (MBMG)**, a state agency
  - Geological mapping
  - Groundwater assessment and investigation
  - Seismology & earthquake studies
  - Fully equipped, production analytical lab licensed by Montana

OTHER INFRASTRUCTURE

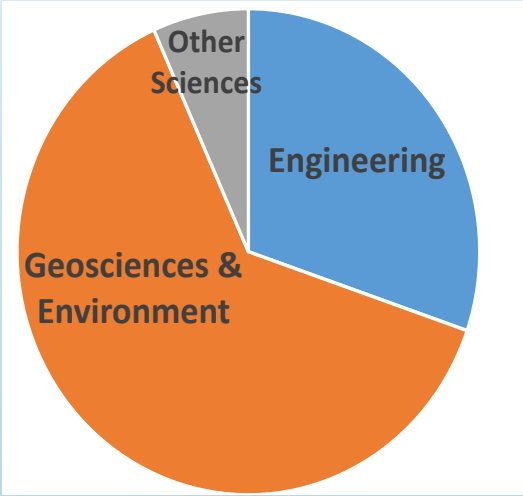
- **Montana's High Performance Computer Cluster with 3D Visualization Room**
- **Underground Mine Education & Research Center**
- **Environmental Engineering & Metal-Contamination Lab**
- **Geomechanics Lab with 330,000-lb Load Frame & Shake Table**
- **Petroleum Engineering & Testing Facilities**

DISTINCTIVE RESEARCH CAPABILITIES

- **Materials**
  - Metallurgy, mining, mineral processing & associated recycling
  - Nanoscience/nanotechnology, plasmonics, & additive manufacturing
  - Growing interest and activity in energetic materials
- **Sustainable Energy & Natural Resources**
  - Petroleum engineering, electric grid, renewables, biofuels, efficiency, & battery technology
  - Geophysical and geological exploration; Geomechanics
  - Groundwater and surface water supply and quality
  - Underground hard-rock mine education & research center
- **High Performance Computing with 3-D visualization**
- **Health care: Informatics & Rural Health**
- **Restoration Ecology & Environmental Sustainability**

CURRENT RESEARCH PORTFOLIO

Funded Research Themes: natural resources, energy, materials science, sustainability, and rural communities



$11 M Research Portfolio

Areas of Expertise

- **Health**
- **Materials Science & Engineering**
- **Energy: Supply, Delivery, & Conservation**
- **Natural Resources, Water, & Geoscience**
- **Restoration Ecology & Environmental Engineering**
- **High Performance Computing & 3-D Visualization**

MATERIALS SCIENCE Ph.D. PROGRAM

- **Collaborative with Montana State Univ. & University of Montana**
  - Over 40 faculty from numerous science & engineering departments
  - Extensive & complementary facilities on all three campuses
  - Core courses and collaborations distance enabled
  - Montana Tech has 9 of the 18 students: 7 doing ARL research

- **Primary research focus areas**
  - Biomaterials
  - Materials for energy storage, conversion, & conservation
  - Electronic, photonic, & magnetic materials
  - Materials synthesis, processing, & fabrication

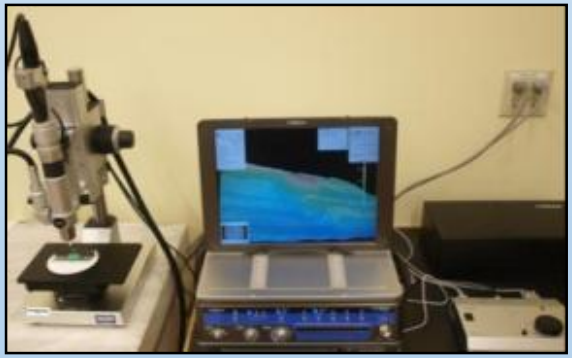
- **Montana Tech's first Ph.D. program!**

EXAMPLES OF CORE MATERIAL CHARACTERIZATION FACILITIES

Materials Characterization Lab

Differential Scanning Calorimeter

X-Ray Diffraction System



Hyrox Digital Microscope

Scanning Electron Microscope/ Energy Dispersive X-ray Analysis System

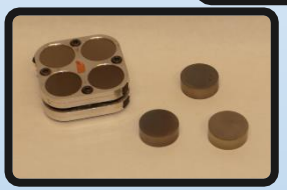
Renishaw inVia Raman Spectrometer

The Center for Advanced Mineral and Metallurgical Processing

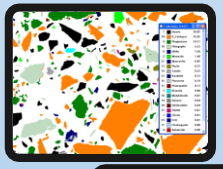
Mineralogical Laboratory

Mineral Liberation Analysis

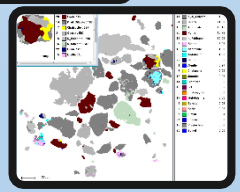
LEO Scanning Electron Microscope with MLA System

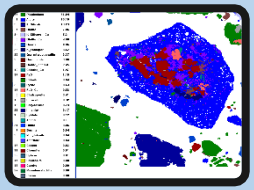


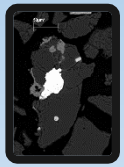
SEM specimen Prep
- Crush
- Grind
- Size (sieve)
- Mineral separation
- Split into representative fractions



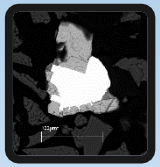
MLA Imaging
- Quantitative Mineralogy
- Mineral grain size
- Mineral associations
- Liberation







"Locked"



Partial Liberation

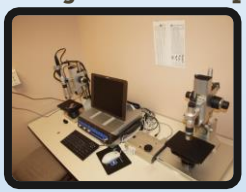
Post MLA Run SEM Examination
- Verification of Mineral ID
- Evaluate Economic Elements
- Mineral Textures
- Occurrence

Imaging Instruments

Table Top SEM

Inspection of Metallic and Composite Test Specimens

3-D Digital Microscope



- Reflected Light Imaging
- Topography
- Metrics

Analytical Instrumentation

X-Ray Fluorescence (XRF)

- Bulk elemental analysis
- Major constituents
- No digestion needed

X-Ray Diffractometer

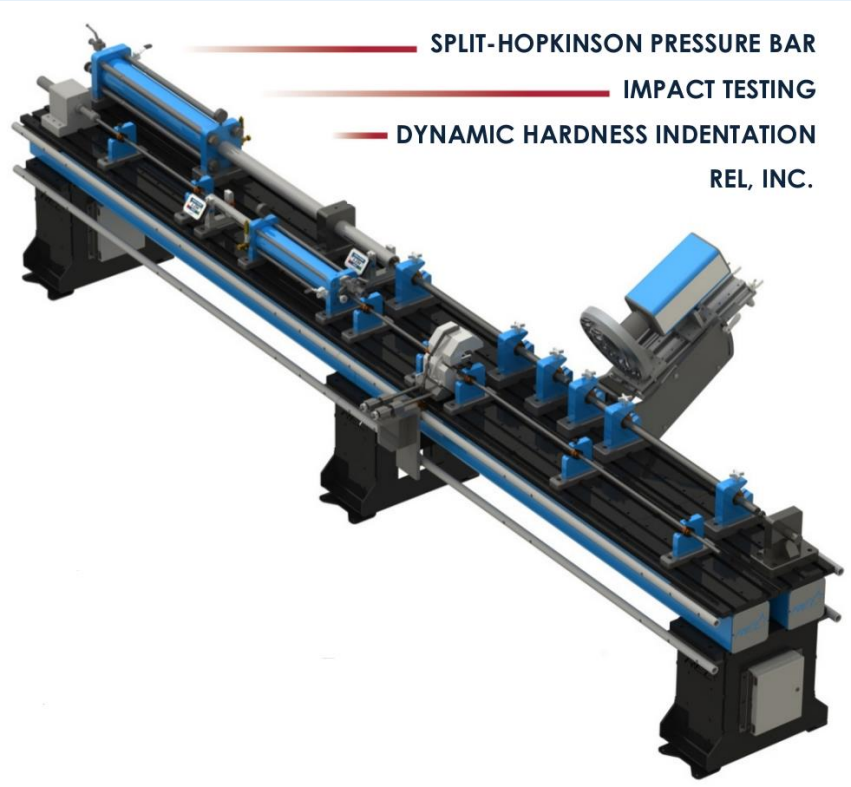
- Powder Diffraction
- Mineral ID
- Crystalline Phases

ICP-AES

Bulk & Trace Element Analysis
- Good Limit of Detection
- Samples Must be Digested

RECENT INSTRUMENTATION PURCHASES

Charpy Impact Test Instrument ordered and slated for delivery middle of October 2015



Split-Hopkinson Pressure Bar instrument for very high strain-rate material testing

- Preliminary 316L specimens to be tested at University of Mississippi in October 2015

EXAMPLE: CURRENT ACTIVE ARMY RESEARCH PROGRAM

Innovations in Materials Processing & Additive Manufacturing

Polymer-Based Functional Materials by Design

Materials Technology: Science & Engineering Research for the Army

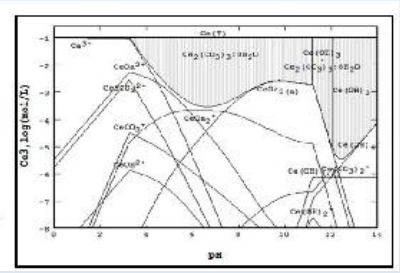
Recovery of Rare Earth Elements with Advanced Processing Technologies

Materials by Design: Synthesis & Sintering of Ceramic & Composite Materials

Metal Casting Imaging & Verification

DETAIL: RECOVERY OF RARE EARTH ELEMENTS WITH ADVANCED PROCESSING TECHNOLOGIES

Flotation

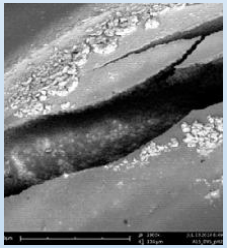


- Flotation region -

$Ce\text{-}CO_3$ system with N-octyl hydroxamate

Good correlation between models and experimental studies

Rare Earth Processing by Flotation Using Novel Collectors and Other Reagents

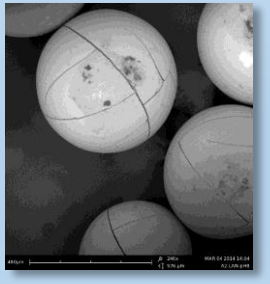


Discovery of previously unknown composite material failure mechanisms

Investigation of Recovery of Rare Earth Metals Using Silica Polyamine Composite Materials

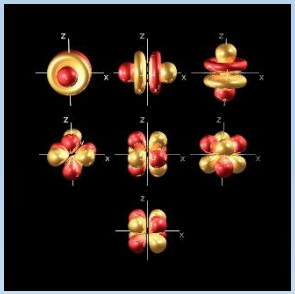
Rare Earth Elements Chloride Purification

Halogenation, vaporization, condensation apparatus



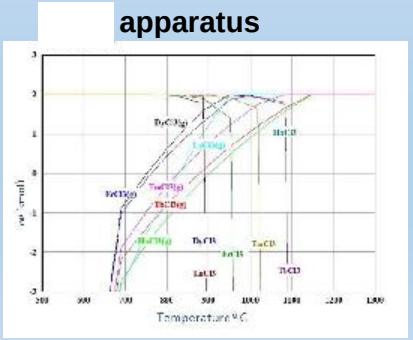
Ion-Exchange

Vapor Phase Extraction



4-f atomic orbitals

Selective REE condensation feasible



ENERGETIC MATERIALS

Energetic Materials is a NEW Research Area for Montana Tech

But:

Tech has both the CAPABILITY and INTEREST in developing research in this direction

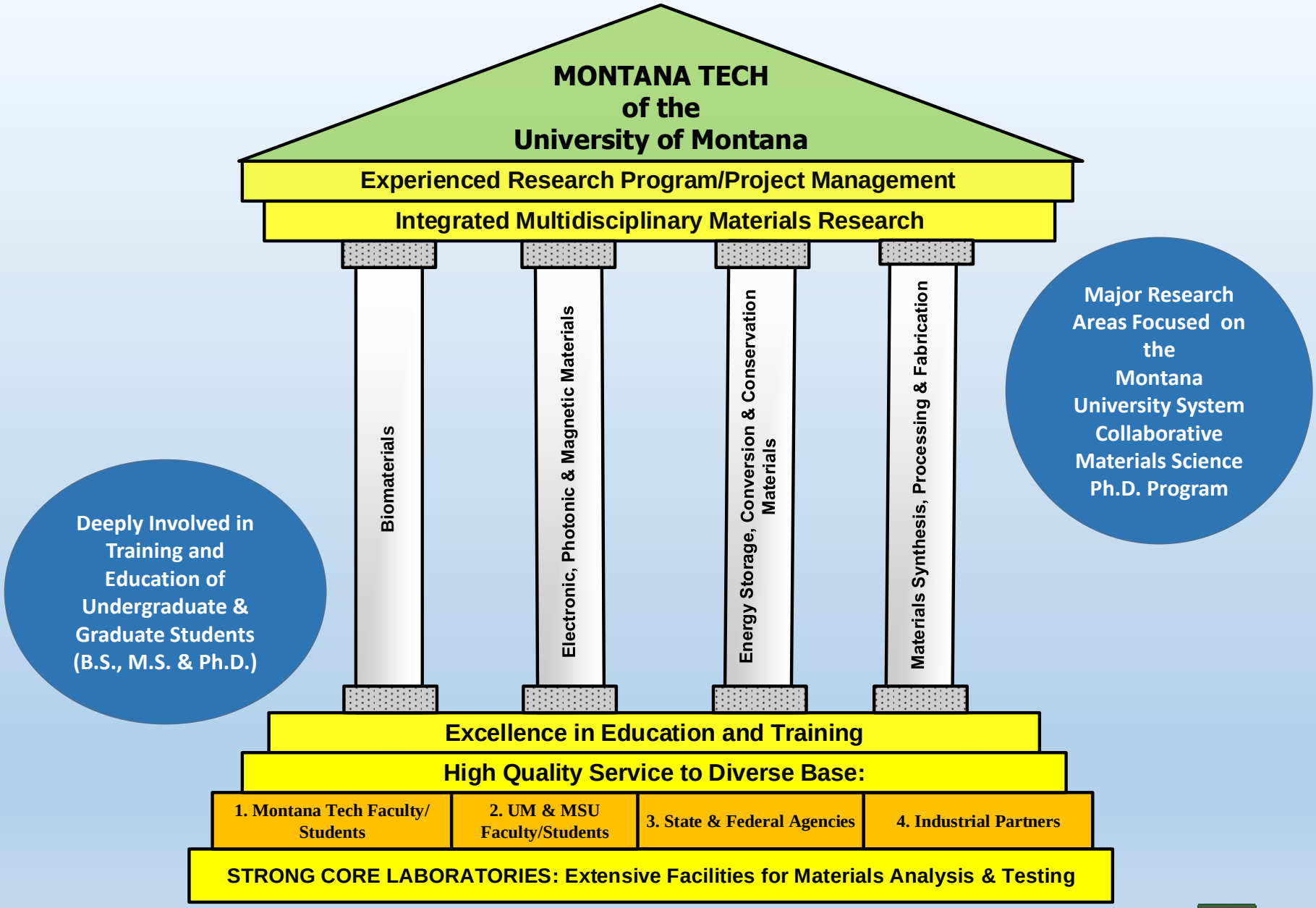
Personnel:

- **Brahma Pramanik (Mechanical Engineering)**
  - **Collaborates with U. of MS Impact Dynamics Laboratory on Mechanical Properties of High-Energy Materials**
- **Douglas Cameron (Chemistry)**
  - **Chemical Reaction Mechanisms & Environmental Impacts**
- **Bryce Hill (Electrical Engineering)**
  - **Electronic Microcontrollers Research, from sensors to robotics**
- **Jack Skinner (General Engineering)**
  - **Nanotechnology Research with background at Sandia**

Partnerships:

- **Developing Partnership with Resodyne Acoustic Mixers**
  - **Subaward Component of recent DOTC Proposal**

WE LOOK FORWARD TO THE POSSIBILITY OF WORKING WITH SOME OF YOU IN THIS IMPORTANT AREA OF RESEARCH


MONTANA TECH
of the
University of Montana
Experienced Research Program/Project Management
Integrated Multidisciplinary Materials Research
Biomaterials
Electronic, Photonic & Magnetic Materials
Energy Storage, Conversion & Conservation Materials
Materials Synthesis, Processing & Fabrication
Major Research Areas Focused on the Montana University System Collaborative Materials Science Ph.D. Program
Deeply Involved in Training and Education of Undergraduate & Graduate Students (B.S., M.S. & Ph.D.)
Excellence in Education and Training
High Quality Service to Diverse Base:
1. Montana Tech Faculty/ Students
2. UM & MSU Faculty/Students
3. State & Federal Agencies
4. Industrial Partners
STRONG CORE LABORATORIES: Extensive Facilities for Materials Analysis & Testing