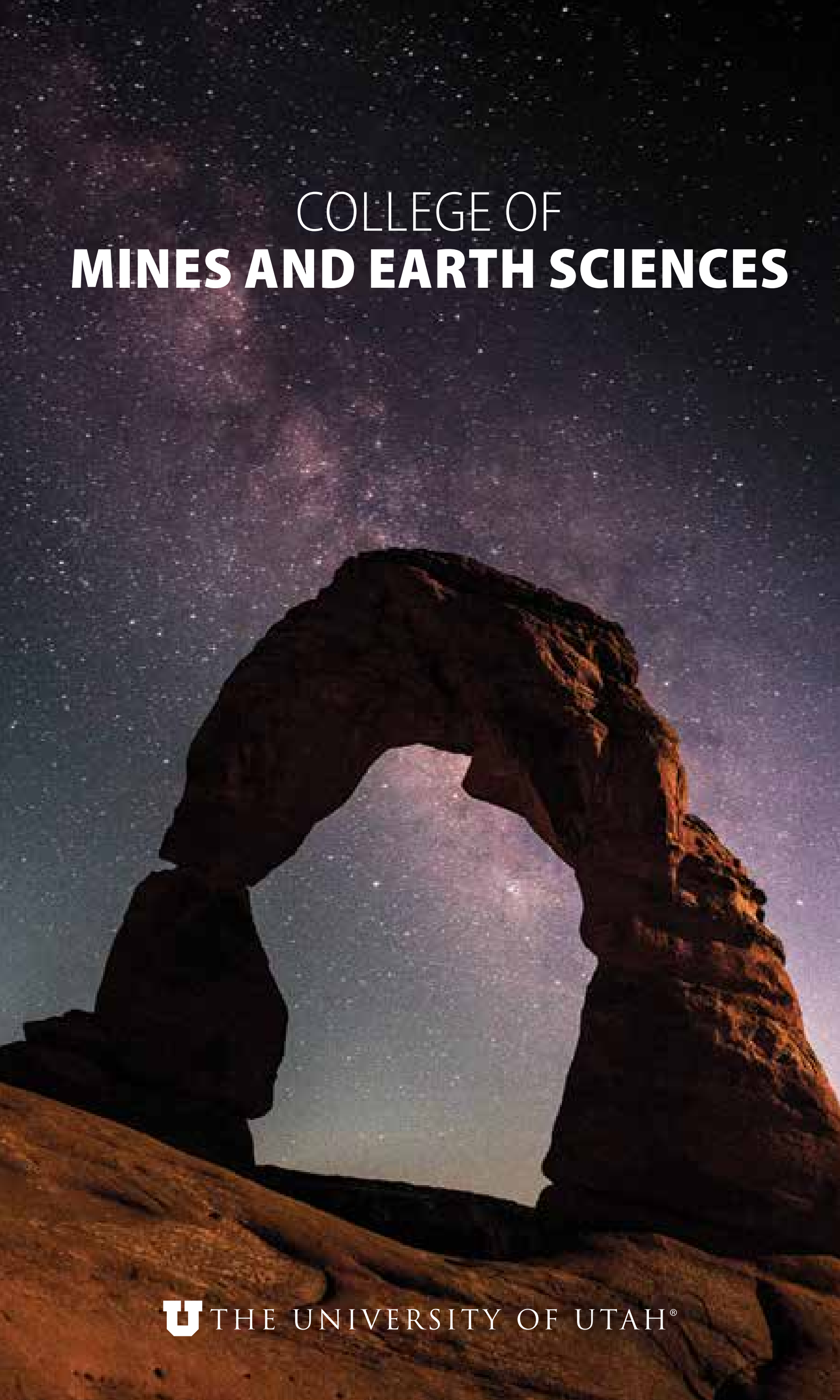
COLLEGE OF
MINES AND EARTH SCIENCES



THE UNIVERSITY OF UTAH®

WELCOME TO
THE WORLD OF CMES RESEARCH!

Research in the College of Mines and Earth Sciences is incredibly diverse, spanning spatial scales from the solar system to the atomic, and engaging with time from billions of years ago with the origin of the Earth, to femtoseconds in the laboratory. Our research programs focus on understanding the physical, chemical, and biological processes that controlled the evolution of the Earth and govern the world we live in today. CMES researchers work to discover and understand fundamental science principles, and to solve real-world problems that affect life on our planet. We seek to improve lives through vibrant and creative science and engineering research, education, and global engagement focused on the Earth and its societal needs.

AIR QUALITY

STUDY AT NATURAL AIR QUALITY LABORATORY WITH PLANES, TRAINS AND AUTOMOBILES

The topography of the Salt Lake valley presents special challenges to air quality. Atmospheric phenomena can trap air pollution in the valley, triggering a cascade of atmospheric chemical reactions. The U studies the emissions of pollutants including carbon dioxide (CO_2), a significant greenhouse gas. The U urban CO_2 observational network is the longest-running in the world. Researchers have also installed air quality sensors on a local news helicopter, a light rail public transit system and Google's StreetView camera cars.

The results show that CO_2 and other pollutants are co-emitted, demonstrating that improving air quality reduces climate impacts. The U has also shown how urban expansion and population growth impacts emissions, as well as how breezes and weather events stir up Salt Lake's atmosphere.

DUST

TRACE THE SOURCES–AND CONSEQUENCES–OF UTAH'S DUST

The deposition of dust on snow accelerates melt both by darkening the snow surface and by enhancing snow grain growth. Snow darkening can also shift the timing and magnitude of meltwater runoff. Dust on snow deposition has been documented in the Wasatch Mountains, where snowmelt accounts for up to 80% of the surface water supply for Salt Lake

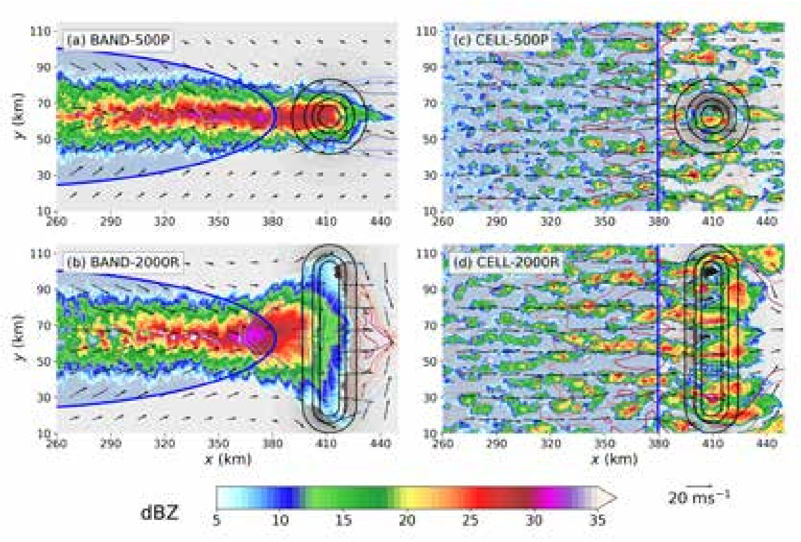
City, but researchers are still studying the impact on snow melt. Atmospheric modeling shows that dust originates predominantly from the west: the Great Salt Lake Desert and the Great Salt Lake dry lake bed. The deposition of dust on snow has important implications for Utah's ski industry and water resources, and lake water levels have been declining, exposing dry lake beds.

A downdraft from a thunderstorm generating dust plumes on the extreme northwestern portion of the Great Salt Lake playa west of Locomotive Springs Wildlife Management Area.

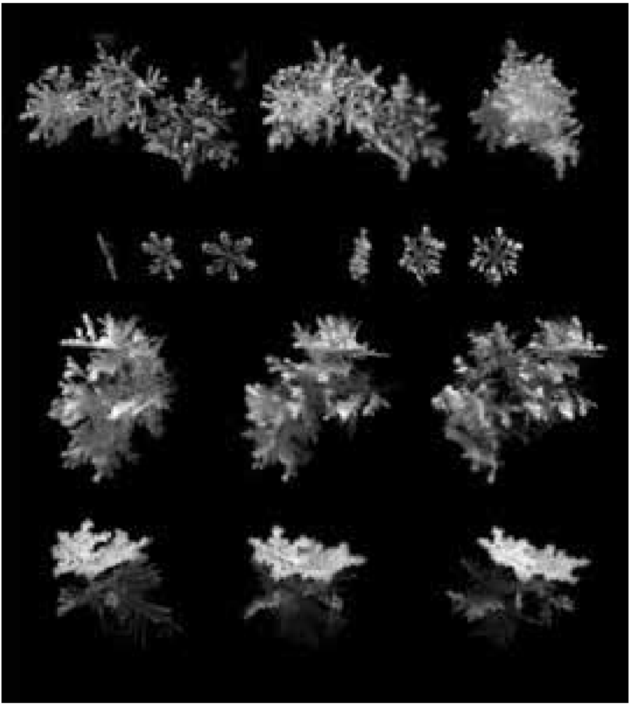
WEATHER FORECASTING AND SUPERCOMPUTING

PREDICT THE FUTURE WITH COMPUTERS—NOT CRYSTAL BALLS

Numerical weather prediction has become a central component of modern weather forecasting. Forecasting models solve a set of complex partial differential equations that govern atmospheric motion and evolution. Department of Atmospheric Sciences researchers use supercomputers to improve numerical prediction and understanding of high-impact weather systems, including tropical cyclones, hurricanes, systems of thunderstorms, and mountainous fog. They are also studying the predictability of flows over mountainous terrain in order to improve forecasts, including the predictability of wintertime fog and severe winter storms.



Simulations of lake-effect storms using a high-resolution cloud-resolving model show the dramatic difference in storm characteristics produced by cold-air outbreaks over oval bodies of water (figures a, b) versus open bodies of water figures c, d). The oval body of water produces an intense lake-effect band concentrated along the lake axis, whereas the open body of water produces scattered, cell-like snow showers. Nevertheless, the intense band produced by the oval lake does not penetrate as far inland and exhibits less enhancement over a downstream peak (figures a, c) or ridge (figures b, d).



CRYOSPHERE AND SNOW

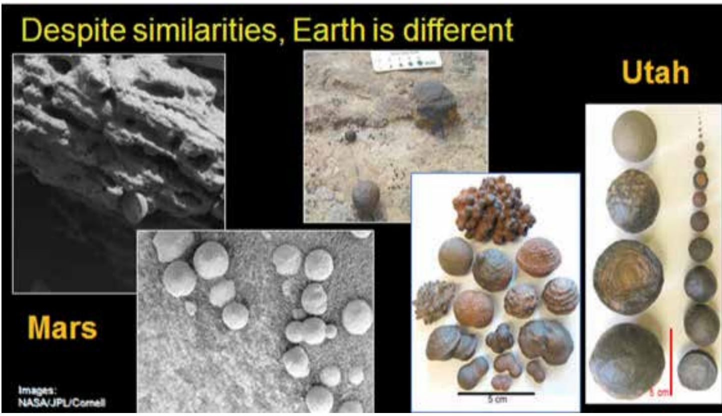
GET ACQUAINTED WITH UTAH'S WORLD-FAMOUS SNOW

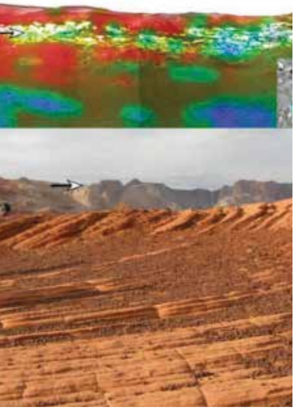
Utah's snow has been touted as the greatest on Earth, and U scientists are with that snow all the way through its hydrologic journey. Meteorologists track incoming storms and use available technology to study the forces that influence the amount and quality of snow that falls in Utah's mountains. Occasional visits by Doppler on Wheels trucks, funded by the National Science Foundation, help teach students how to employ Doppler radar for studies of small-scale phenomena. Scientists also watch the snow fall in three dimensions, aided by the Multi-angle Snowflake Camera developed at the U that continually captures images of falling snowflakes from a site at 8500′ elevation in the Wasatch Mountains. U researchers also keep an eye on snow's role in Utah's water supply, modeling the future of snowpack in a warming world and working to clarify the relationship between mountain snow and valley water.

GLOBAL CHANGE AND SUSTAINABILITY CENTER

COLLABORATE ACROSS COLLEGES TO TACKLE GLOBAL CHANGE

The Global Change and Sustainability Center (GCSC) is an interdisciplinary hub catalyzing research on global change and sustainability. Housed in CMES, the GCSC was created in 2009 by a group of faculty from multiple colleges with a shared interest in environmental research and training. The GCSC has grown to include researchers from 10 colleges. It incentivizes and facilitates interdisciplinary research at the University of Utah through seminars, graduate fellowships, student research grants, travel grants, faculty seed grants, an interdisciplinary graduate certificate in sustainability, postdoc mentoring, think tanks for faculty to explore shared research interests, and more.


Despite similarities, Earth is different
Utah
Mars
Images:
NASA/JPL/Cornell
5 cm



MARS

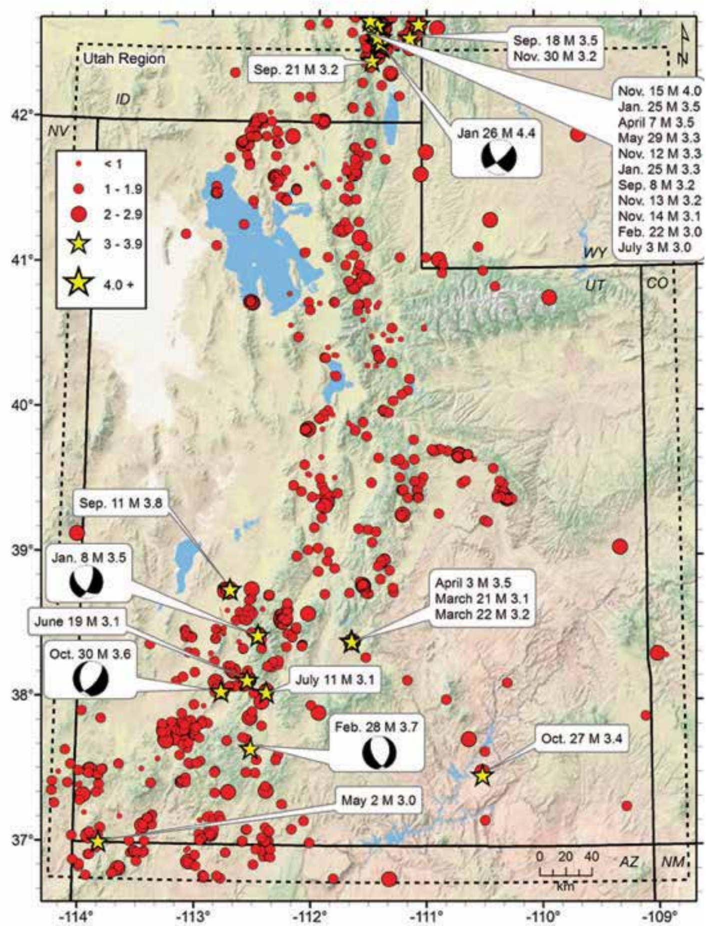
SOLVE MARTIAN MYSTERIES WITH UTAH ROCKS

As scientists learn more about Mars via robotic rovers, they also uncover geologic mysteries. When the NASA Mars Exploration Rover Opportunity discovered spherical concretions dubbed "blueberries," U researchers turned to similar mineral masses found in southern Utah to understand the geology of the blueberries. Surface features remotely imaged on Mars indicate past watery conditions, with the tantalizing potential for extraterrestrial life, and terrestrial analogs in Utah's sedimentary rocks are valuable for deciphering past histories and the possibility of "habitability" of Mars.

WILDLIFE ECOLOGY AND ISOTOPES

POLICE THE IVORY TRADE – WITH SCIENCE

Poaching of elephants for the illegal trade of ivory is a major wildlife ecology problem. Geologists from CMES help enforce global policies that ban this illegal trade using their unique capabilities to accurately date carbon and strontium isotopes in seized ivory. By measuring radiocarbon they can determine the date of death of elephants using the remnant signal of nuclear weapons testing; strontium isotope ratios in combination with genetics can determine the geographic origin of seized ivory. The work has influenced worldwide policies that deter ivory trade.


Utah Region
ID
NV
WY
UT
CO
AZ
NM
< 1
1 - 1.9
2 - 2.9
3 - 3.9
4.0 +
Sep. 18 M 3.5
Nov. 30 M 3.2
Sep. 21 M 3.2
Nov. 15 M 4.0
Jan. 25 M 3.5
April 7 M 3.5
May 29 M 3.3
Nov. 12 M 3.3
Jan. 25 M 3.3
Sep. 8 M 3.2
Nov. 13 M 3.2
Nov. 14 M 3.1
Feb. 22 M 3.0
July 3 M 3.0
Jan 26 M 4.4
Sep. 11 M 3.8
Jan. 8 M 3.5
June 19 M 3.1
Oct. 30 M 3.6
July 11 M 3.1
April 3 M 3.5
March 21 M 3.1
March 22 M 3.2
Feb. 28 M 3.7
Oct. 27 M 3.4
May 2 M 3.0
0 20 40
km
42°
41°
40°
39°
38°
37°
-114°
-113°
-112°
-111°
-110°
-109°

EARTHQUAKES/SEISMOLOGY

KEEP WATCH OVER A MAJOR FAULT AND THE 2.2 MILLION PEOPLE WHO LIVE ON IT

U scientists keep a close eye on two of the biggest geological hazards in the Intermountain West. The University of Utah Seismograph Stations (UUSS) operates and maintains a network of 252 seismic stations in the Utah region and around Yellowstone National Park. UUSS locates over 1,500 earthquakes in the Utah region in a typical year.

Earthquakes occur throughout the state, but the hazard is highest along the Wasatch Fault, which parallels an urban corridor that houses 2.2 million people. If a quake of magnitude 7 were to shake the Salt Lake segment of the fault today, we could expect up to 10,000 casualties and $30 billion in economic losses.

When earthquakes happen, UUSS provides prompt and accurate information related to seismic events, including their effect on the built environment. Follow @UUSS_Quake_Info on Twitter for real-time updates.

ARCHES

LISTEN TO THE VOICES OF ROCK ARCHES AND PINNACLES

Rock arches are far from static: they are dynamic natural features that bend, sag, sway and shake in response to different environmental forcings. Researchers use ambient vibration seismic measurements to study the dynamics of natural rock arches, including prominent natural landmarks. The goal is to understand how arches respond to their environment and

ultimately discern changes in internal strength over time. They have found that an arch's resonance is related to the arch's overall mass and stiffness, and monitoring over time can provide indirect evidence of internal change. This research will lead to new understanding of the life-cycle of natural arches, their response to external loads, and failure processes leading to their eventual collapse.

View looking east toward the Mineral Mountains, during the drilling of well 58-32, the initial test well at the FORGE site. The well reached a temperature of 199ºC. at a depth of 7536 ft.

FORGE

EXPLORE NEW GEOTHERMAL TECHNOLOGY IN A WORLD-CLASS FIELD LAB

Milford, Utah, south of Salt Lake City, is the site of the U.S. Department of Energy's FORGE project, with the University of Utah's Energy and Geoscience Institute as the primary contractor. The $140 million project is a laboratory to test new technology that can make geothermal power possible anywhere in the world, and not just in areas with hot springs.

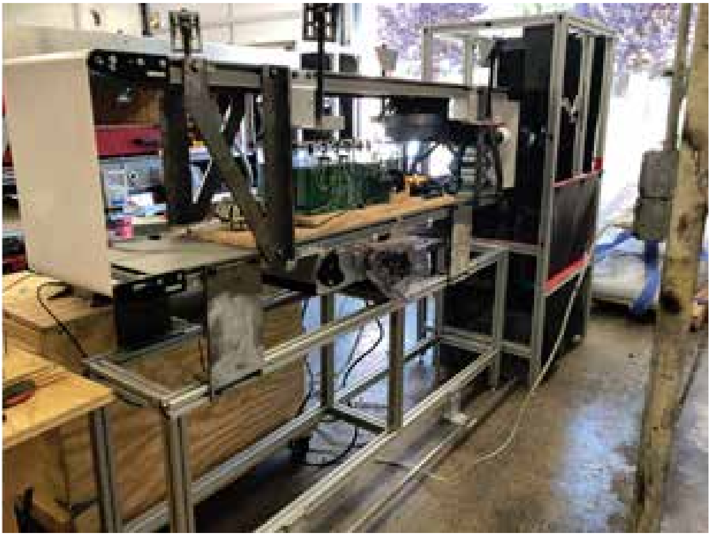
The field laboratory consists of two wells drilled into granitic rock where temperatures exceed ~175 ºC. The two wells will be hydraulically stimulated to create a fractured reservoir. Water will be circulated between the wells while nearby wells will be used to monitor pressures, temperatures, seismic activity, and fracture growth. The U will provide seismic monitoring for the project, studying the drilling and development of the geothermal wells and control of underground fracture formation and growth.

BONNEVILLE SALT FLATS

STUDY ONE OF THE WORLD'S MOST ALIEN LANDSCAPES

The Bonneville Salt Flats are a singular natural, recreational and economic resource. But the salt flats are under pressure from declining lake levels and mineral extraction. Environmental conditions influence the composition and character of sediments, minerals, and fluids in systems such as the Bonneville Salt Flats that are shaped by evaporation. Ongoing research

on the salt flats helps constrain the timescales and processes of change in the geologic past, present, and future. The sustainability of the salt flats landscape is influenced by many dynamic processes including climate and hydrology, groundwater flow, sediment deposition and erosion, microbiology, and human uses including mining and high-speed racing.



ADVANCED RECYCLING METHODS

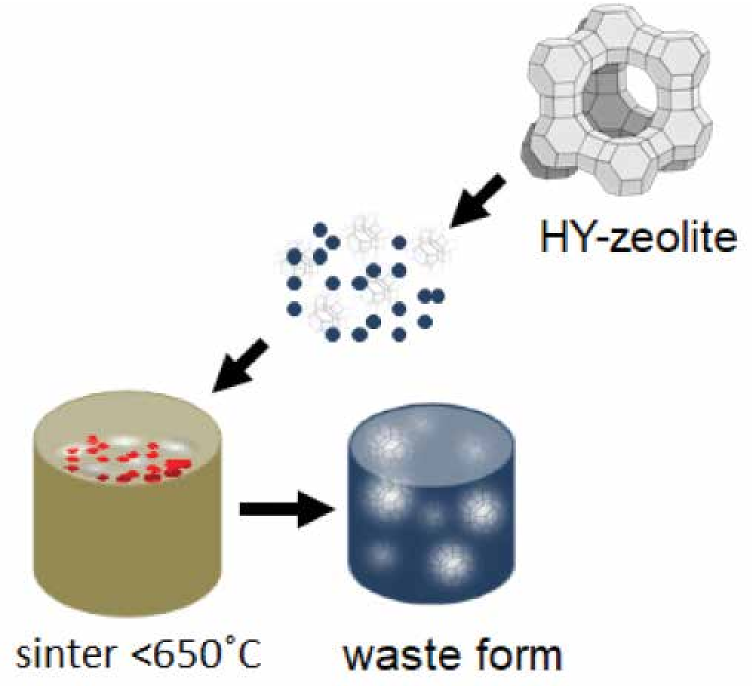
SORT THE UNSORTABLE IN METALS RECYCLING

Many products that are thrown away or recycled contain metals with concentrations well above virgin ore grades. Recovered scrap metals are anticipated to become primary resources for iron, aluminum, and copper in the next 30+ years. Automobiles and old appliances are shredded to recover scrap metal that mostly contains aluminum, copper, brass, and zinc – but without technology to sort fine-sized scrap. The CMES researchers have developed a one ton per hour sorter. The technology has received worldwide attention for its potential to minimize material needs, save energy, and reduce the environmental footprint of the materials we use.

SMART MATERIALS

FIND INEXPENSIVE WAYS TO MAKE INCREDIBLY USEFUL MATERIALS

Materials called “magnetostrictive” have two intriguing properties. They expand when a magnetic field is applied and change magnetization when a stress is applied. These properties make magnetostrictive materials very useful as actuator elements to deliver large forces such as deploying spacecraft antennas, pressurizing antilock braking systems and generating underwater sonar signals. They are also useful as sensors in energy generators. But magnetostrictive materials are made of expensive rare-earth rich alloys. Researchers at the University of Utah and collaborators have discovered magnetostriction in inexpensive, rare-earth-free alloys. This allows development of new, low-cost magnetostrictive alloys for wide use in sensing, actuation and power generation.


HY-zeolite
sinter <650˚C
waste form

NEXT GENERATION NUCLEAR TECHNOLOGY

ENGINEER A NEW GENERATION OF NUCLEAR REACTORS

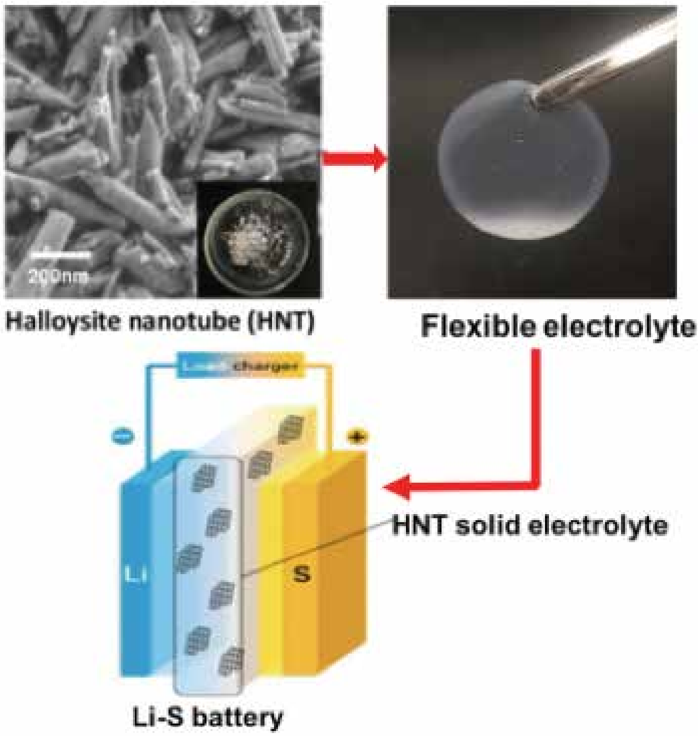
Nuclear power is one of the key options for sustainable energy. Molten salt reactors in particular are currently the focus of intense development by both the industry and the U.S. Department of Energy as advanced and safe next-generation nuclear technology. Molten salt chemistry, critical to the development of these reactors, is a focus of research in the Department of Metallurgical Engineering. Researchers study how to purify these salts, how to measure and mitigate corrosion and how to minimize waste generation in sustainable energy production. This research also impacts other applications of molten salts, including converting thermal solar energy into electricity as well as recycling conventional nuclear fuel.

BATTERIES FOR LARGE-SCALE ENERGY STORAGE

SHAPE UTAH'S MINERALS INTO BETTER BATTERIES

Large-scale application of lithium batteries has been hampered by electrolyte decomposition at high voltages and potential fire issues. CMES researchers developed new electrolytes, made from advanced halloysite nano-tube solid polymers which address the problems of lithium batteries and improve performance. And halloysite can be found in our backyard – Utah's Tintic mining district is a major source.

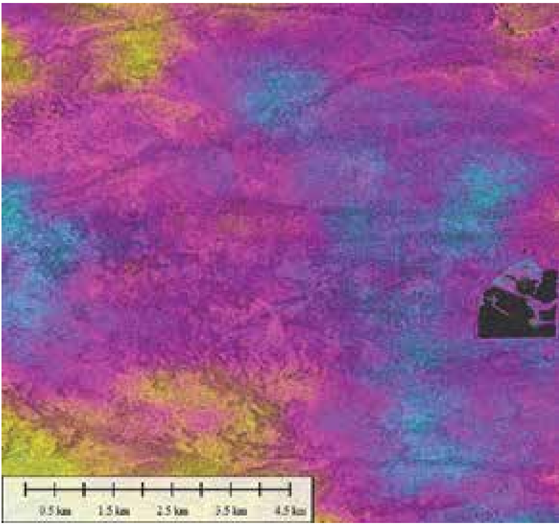
U researchers are also developing applications of metal hydrides for thermal energy storage. These "thermal batteries" could someday heat and cool electric vehicles. The Department of Energy featured the thermal batteries at the 2014 Energy Innovation Summit.


200nm
Halloysite nanotube (HNT)
Flexible electrolyte
charger
Li
S
HNT solid electrolyte
Li-S battery

GROUND CONTROL SAFETY

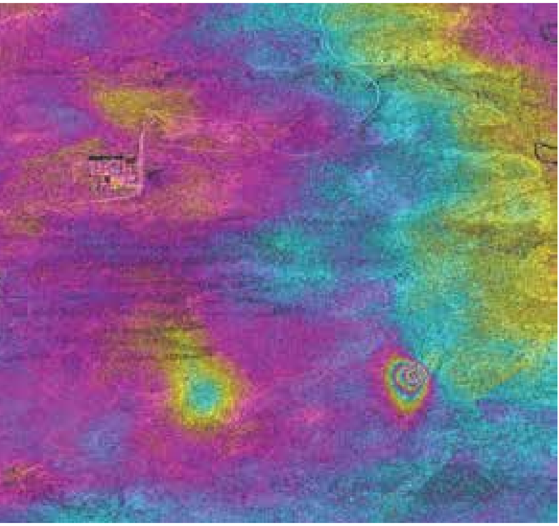
KEEP WATCH OVER MINES AND MINERS FROM SPACE

In mine safety, the practice of ground control helps maintain safe excavation in rock. Applied research using satellite-based DInSAR (Differential Interferometric Synthetic Aperture Radar) and seismic monitoring and analysis advances our understanding of how mining affects seismicity and the mechanics of rock layers. Satellites use radar waves to measure distance to the Earth's surface. As the Earth deforms, whether due to natural causes like earthquakes or manmade causes like mining, the distance from



Surface deformation measured by DInSAR.

the satellite to the Earth changes, and radar waves can measure this change. In addition to earthquakes, seismic events can have manmade sources, like mining, and seismic analysis can be used to monitor how the mechanical stress in rocks change as material is extracted underground. Seismic analysis and deformation monitoring using DInSAR can improve ground control safety by identifying conditions and mechanisms that could lead to mine instability.



An example of information extracted from text. Patterns in extracted fields can serve as early warning indicators.

Raw Data MSHA Description

- after changing a deck screen, the miner was crawling out from between the screen deck and misplaced their footing causing them to dislodge the board placed as a safeguard over an opening. the miner fell through the opening and struck their head.

Extracted Info Accident

- Accident: fell, through, opening

Extracted Info Causes

- changing, deck, screen, crawling, out, misplaced, footing, causing, dislodge, board, placed

Extracted Info Other Details

- struck, head

MAKING INDUSTRIAL SITES SAFER THROUGH MACHINE LEARNING EARLY WARNING SYSTEMS

IMPROVE UTAH MINES' EFFICIENCY AND VALUE

The ai.sys group in the Department of Mining Engineering is working with the National Institute for Occupational Safety and Health to detect leading indicators for hazards from safety data at mine and other industrial sites. The data may be in the form of description of conditions and/or behaviors observed at work sites. Natural language processing based machine learning algorithms are being developed to detect problem conditions and behavior. In one instance, an industrial site that is a customer of a Utah-based safety app (an early partner in the project) was given actionable intelligence to address hazards. Tools are currently being developed to analyze the Mine Safety and Health Administration's (MSHA) national database to detect leading indicators on a larger scale.

COLLEGE OF
MINES AND EARTH SCIENCES

ATMOSPHERIC SCIENCES

Atmospheric scientists advance knowledge about weather and climate. They use a wide variety of observational and computer-based modeling tools to study the physics, dynamics, and chemistry of Earth's atmosphere. They work to provide critical data and context to address the challenges posed by hazardous weather and climate change.

GEOLOGY AND GEOPHYSICS

Geoscientists study the Earth's physical structures and the processes that act on them. They also research the most economic and sustainable ways to utilize the Earth's resources. Geoscientists gain skills in chemistry, biology, physics, engineering and computer science to understand the composition, structure and history of the Earth.

METALLURGICAL ENGINEERING

Metallurgical engineers innovate, design, implement and improve the processes that transform particles and metals into modern products that improve the quality of our lives. They work to meet the mineral and metal product needs of our modern civilization in an environmentally responsible way.

MINING ENGINEERING

Mining engineers combine engineering, geology and mining to discover, evaluate and develop mineral deposits. They recover mineral commodities from the Earth safely, economically and sustainably to meet the demands of modern civilization.

College of Mines and Earth Sciences
University of Utah
115 South 1460 East, Room 205
Salt Lake City, UT 84112-0102
(801) 581-8767
www.cmes.utah.edu

@UOFUCMES