IGS FY 2023 ANNUAL REPORT
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ON THE COVER
Seismic monitoring station installed south of Stanley, Idaho as part of the Idaho Seismic Network. The station is hosted by the Idaho Rocky Mountain Ranch, and it is listed in the International Federation of Digital Seismograph Networks as WW.IRM. Data from this and other stations of the Idaho Seismic Network are being recorded and transmitted in near-real time to the EarthScope consortium for public consumption. To see the daily recording from this instrument visit: https://service.iris.edu/irisws/timeseriesplot/1/query?net=WW&sta=IRMR&loc=00&cha=HHZ&starttime=currentutcday&helicordermode=true&format=png.
Looking back at a full year of accomplishments, we are sometimes drawn to find a single word that would summarize the essence of all that has happened on the many fronts, subjects, topics, projects, and activities of the Idaho Geological Survey (IGS) in FY 2023.

I can confidently say that this year the word is growth.

IGS has grown in virtually all aspects of its activities. Our staff has increased the coverage of geologic mapping in numerous project areas, providing new insights on both the regional geology and the economic potential of various regions with a strong focus on critical minerals. We have been working across the state to identify new resources, contribute to a deeper understanding of historic districts, and experiment novel approaches to add value to areas of already proven potential. We have expanded our understanding of active tectonics and surficial faulting in areas affected by recent and ongoing seismicity bringing us a step closer to a detailed chronology of repeated seismic occurrences. On a similar token, IGS was able to grow the number of earthquake monitoring instruments deployed in the state, effectively installing the skeleton of the first seismic network in IGS history. We have expanded our network of collaborations, and the hydrogeology program has released impactful publications and laid out the basis for future environmental work while making headways in ongoing critical projects on water budgets in the arid south-central region of Idaho. Our understanding of the petroleum system in the western Snake River Plain has progressed to the point of being able to define a comprehensive model of hydrocarbon generation that will provide invaluable insights to interested parties. We are exploring new technologies and building capacity in our databases, and our instrumentation pool is also expanding with a fleet of handheld instruments that allows us to ground truth the growing amount of geophysical and geochemical data being acquired from airborne platforms over vast swaths of Idaho.

IGS has also grown in size! We have added considerable space to our offices in both Moscow and Boise, and new staff have joined our ranks. In its growth, IGS has been greatly assisted by the Office of Research and Economic Development at the University of Idaho, which has provided both physical spaces and funds in support of IGS operations and two post-doctoral research scientist positions. And so grows and deepens the long and productive relationship between our agency and our home institution.

As we grow in our interests, projects, collaborations, and accomplishments, we keep a close eye on our legislative mandate and our statutory mission, and we keep focusing on the needs of the state and its constituents to provide the necessary unbiased geologic information that are instrumental to foster and safeguard Idaho’s prosperity.

I hope you will take a few minutes to learn more about our activities through the pages of this annual report, and I thank you in advance for your interest.

Claudio Berti
Director and State Geologist
Completed groundwater budgets for
the Big Lost River Basin in south-
central Idaho with publication by
the U.S. Geological Survey (USGS)
as a chapter in a USGS scientific
investigation report.

Continued work with the Idaho
Department of Water Resources
(IDWR) on Phase 2 of a hydrogeologic
investigation of the Raft River Basin
in south-central Idaho and northern
Utah. IGS is preparing a hydrogeologic
framework and groundwater budget.

Completed work on a USGS
Earthquake Hazard Program
grant to investigate the Sawtooth
fault. Working collaboratively with
Idaho State University and BGC
Consultants, we mapped the entire
fault zone, measured scarp heights,
and dated three faulted landform
surfaces. We documented several
unknown fault scarps, including the
Cape Horn fault and scarps at Shake
Creek and Smiley Creek.

Contributed to a separate paleoseismic
trench study of the Sawtooth fault led
by the USGS. This is the first
paleoseismic trench excavated on the
Sawtooth and it exposed evidence
for at least one Holocene earthquake
event on the northern part of the fault.

Revised or remapped all active faults
south of the Snake River Plain as
part of the DOE-funded INGENIOUS
geochemical project. New LiDAR has
enabled improved mapping in many
areas. New mapping was compiled
with similar efforts from neighboring
states to identify favorable structural
settings for geothermal exploration.

Initiated a new effort to establish and
survey a dense network of campaign
goetic monuments. Periodic
surveying of these monuments
measures crustal motion allowing
for a better understanding of active
tectonics. IGS machined 24 geodic
monuments and acquired 10 GPS
receivers. Installation and surveying of
monuments will be an ongoing effort.

Continued work on STATEMAP:
- Targeted mapping of the western
half of the Elk City 30' x 60' quadrangle successfully filling in
the remaining gaps required to
complete the coverage needed to
publish at 1:75,000 scale. Progress
has also been made on edge
matching the western portion of the
eastern half of the 30' x 60' sheet
to ensure proper agreement with
future surveying efforts.
- Continued work in the Salmon area
with a focus on the geology of the
area north and northwest of the
Beartrack mine where the Napoleon
Hill and Pine Creek Ridge 7.5'
quadrangles were mapped.
- Completed geologic mapping of the
Weiser South and the Payette 7.5'
quadrangles. The latter quadrangle
highlights the southwest Idaho
oil and gas field. Completed the
final 7.5’ quadrangle of the Weiser
western half 30’ x 60’.
- Addressed edge mapping issues
across nine previously mapped
quadrangles in the Preston
project area and prepared these
quadrangles for publishing.
- Where coverage is available,
IGS augments mapping efforts
with LiDAR-derived imagery.
Imagery interpretation has led
to the identification of previously
unmapped faults, the location of
other unconstrained tectonic
lineaments, and historic placer
operations, significantly improving
our understanding of their
contribution to geologic hazards,
mapping, mining history, and their significance in
the geologic history of Idaho.

- Continued to implement the Geologic
Map Schema (GeMS) database
standard for all new geologic mapping
activities, an effort IGS initiated in FY
2022.
- Increased the coverage of GeMS-
compliant geologic map databases
to now include more than 212 7.5'
quadrangles in five project areas
throughout Idaho. By the end of FY
2023, approximately 33% of areas
mapped by IGS have been brought
into GeMS compliance.
- Published three Digital Web Maps,
one Digital Analytical Datasets, and
one GeoNote. Republished two Digital
Databases (see Publications and
Activities section).
- Continued petrographic and analytical
work to characterize the highly
oxidized thorium and rare earth
bearing material at the Diamond Creek
property in Lemhi County. Work is part of
a University of Idaho engineering
project investigating potential new
biological related processing of the
material to extract rare earths.

- Launched the Geochemical
Reconnaissance of the Western
Phosphate Basin project, funded by
USGS Earth MRI (Earth Mapping
Resource Initiative) in collaboration
with state surveys in Wyoming,
Utah, and Montana. The primary
objective of the project is to provide
foundational information and data on
the occurrence of critical minerals
such as Chromium, Vanadium,
Fluorine, and Rare Earth Elements
(REEs) within the Western Phosphate
Field of Idaho, Montana, Utah, and
Wyoming. Activities to date include
extensive literature compilation and
digitization and field collecting of over
800 samples from active mine sites,
core, and outcrops over the 4-state
region for chemical analysis.

- Reported on Idaho’s mining and
exploration activity (Annual mining
review materials can be found on
the IGS Current & Historic Mining
Activity Webpage under Regional
Development):)
  - A booming construction business
was good for sand and gravel
operators.
  - Mines continued to operate in
north Idaho and the southeast
Idaho phosphate district, and many
exploration projects were active.
  - In June 2023, a judge revoked a
prior mine plan approval for Bayer’s
Caldwell Canyon phosphate project
due largely to concerns over sage
grouse.
  - In March 2023, low cobalt prices
forced Jervois Global to suspend
final construction at their Idaho
Cobalt Operation in Lemhi County,
although exploration drilling was
underway in the fall with support
from the U.S. Department of Defense.

- A notable highlight was the October announcement of a “discovery hole” indicating strong copper porphyry style alteration and mineralization at the Hercules Silver Corporation property west of Cambridge. Assays for drill hole HER-23-05 included 185 meters averaging 0.84% Cu, 111 ppm Mo, and 2.6 g/t Ag. The Hercules deposit is within the Triassic to Jurassic western Idaho accreted terrains which have seen little exploration in recent decades.

- Completed digitization of the mineral property files for the Hamilton 1° x 2° quadrangle. Eighty-seven files are available for download from the web application.

- Data-mined the 1993 and 1994 Regional Development files and the 1905 Idaho State Mine Inspector Report. From these seven documents, 637 new “relates to mine properties” were made, including 75 references.

- Conducted a first-pass review of 19 Regional Development files from 1995 through 2003. File data were entered, and 842 “relates to mine properties” were made.

- Digitized and cataloged a portion of the expansive Don Adair Collection. To date, the processed mineral property files mainly cover Adair’s exploration, research, or mining work in the Cuddy Mountain, Weiser, and Boise Basin areas.


- Redesigned tables and made improvements to existing data in the Oil and Gas Database and entered 189 documents, 220 LAS files, and 146 logs, creating nine new well records.

- Digitized over 240 paper formatted wireline logs from 17 wells located in the southeastern portion.

- Digitized approximately five hours of analog tape of video inventories of Abandoned Mine Lands, related in the Mines database and uploaded to the IGS YouTube channel.

- Migrated IGS interactive web map applications to ArcGIS Online platform.

- Analyzed data from gas and fluid samples previously collected by the IGS from sixteen wells in the producing areas of the western Snake River Basin to understand the origin and genesis of the produced hydrocarbons in the region. Findings from the geochemical characterization help address questions regarding the source and generation of crude oil and natural gases hydrocarbons which is crucial for effective exploration activities.

- Conducted ongoing seismic interpretation of igneous intrusions from beneath the western Snake River Plain. Intrusions related to Miocene age volcanism in the western Snake River Plain potentially play a role in the generation of hydrocarbons. Understanding their distribution contributes to exploration endeavors by pinpointing potential hydrocarbon-rich regions enabling informed decisions in petroleum exploration.

- Constructed virtual outcrop models using drone-based imagery and photogrammetry from exposures in the area of Oreana, Idaho and Vale, Oregon to aid in geological characterization of outcrops from the western Snake River Plain that serve as potential analogs for producing reservoirs at the Harmon and Hamilton fields in Payette County, Idaho.
FY 2023 By the Numbers

- Collaborating partners: 92
- Active awards: 14
- Funding partners: 6
- Publications: 15
- Professional presentations: 32
- Educational presentations: 10
- Web products: 4
- Outreach Activities: 10
- Media interviews: 9
In FY 2023, IGS completed a joint hydrogeologic investigation of the Big Lost River Basin in south-central Idaho with IDWR and the USGS. IGS prepared groundwater budgets for the basin published as Chapter C of a USGS multichapter report describing the water resources in the basin. Two separate budgets for the aquifer were developed, one above and one below Mackay Dam. The budgets span a 20-year period (2000–19), characterizing average conditions, a dry year (2014), and a wet year (2017). The broader investigation provided for data and interpretation for assisting water-resources decision making and future groundwater modeling. The groundwater budget report may be accessed from the USGS URL: https://pubs.usgs.gov/publication/sir20215078C, and additional project-related reports and resources may be accessed from the IDWR URL: https://idwr.idaho.gov/water-data/projects/big-lost/hydrologic-investigation/.

A groundwater budget is a conceptual and numerical accounting of inflow (recharge) to groundwater and outflow (discharge) from groundwater. The difference between the sum of all inflows and outflows represents the budget residual. The residual can be positive or negative and is comprised of groundwater outflow exiting the basin, the change in groundwater storage, and uncertainty and errors in the budget. Figure 4 from the report (bottom right) summarizes the total mean annual relative percentage contributions for the predominant groundwater-budget terms.

The results of the study convey an interconnected and complex hydrologic response to various climatic and water-use trends. The part of the basin above Mackay Dam typically has a positive groundwater residual derived from snowmelt recharge to tributary canyons and areal recharge in excess of groundwater pumpage for irrigation demand. This supply is used to meet irrigation demand above Mackay Dam and to provide for water supply below Mackay Dam. On average, groundwater inflow from above Mackay Dam to below Mackay Dam, assuming negligible reservoir storage effects, accounts for about 25 percent of the total groundwater recharge below Mackay Dam. Considerable recharge to groundwater below Mackay Dam occurs through seepage from the Big Lost River and canals and ditches. Most groundwater discharge from the aquifer is through irrigation pumping. The water supply below Mackay Dam is highly dependent on available upstream surface-water flows, the magnitude of the groundwater residual from above Mackay Dam, and annual variability in local groundwater conditions.
Halfway Gulch Fault Investigation

In FY 2023, IGS staff completed an investigation of the Halfway Gulch fault. The project was funded by an Earthquake Hazards Program grant from the USGS and was performed in collaboration with geologists at Lettis Consultants International. The Owyhee Mountains fault system is a normal fault system bounding the southwest margin of the western Snake River Plain graben. The Halfway Gulch fault, a section of the Owyhee Mountains fault system, has a clearly expressed and geomorphically youthful rangefront scarp that represents offset of multiple generations of alluvial fan and terrace deposits. The Halfway Gulch fault is located less than 100 km south of Boise, Idaho, a metropolitan area with a population of more than 730,000 people. Despite the apparent youthfulness of the Halfway Gulch fault, large uncertainties exist regarding its recency of activity, slip rate, geometry, and recurrence interval. Previous work by documented five earthquake events in the last ~25,000 years on a nearby zone of faults that includes the Water Tank fault and Parker Ranch fault, located 8 km NNE of and parallel to the rangefront strand of the Halfway Gulch fault.

IGS conducted detailed mapping of the Halfway Gulch fault zone and dated key surficial deposits to better understand the history of the fault and its potential for future activity. New Federal Emergency Management Agency (FEMA)-funded 0.5-m resolution LiDAR collected in 2019 allowed mapping of the fault and surrounding surficial deposits in detail. IGS identified additional strands of the fault that were previously unmapped. The new mapping documents two distinct zones of deformation along the Owyhee Mountains range front, including a 3- to 5-km-wide zone of relatively short and linear fault strands associated with the Water Table fault zone and a well-defined Halfway Gulch fault zone along the rangefront that occurs as a primary northeast-dipping strand with several prominent antithetic strands located about 600 to 700 m to the northeast.
IGS dug soil pits in several alluvial fan surfaces to collect dating samples or interpret the approximate age based on soil development. The large 8-9 m high fault scarp of the Halfway Gulch fault displaces an alluvial fan deposit that is estimated to be ~130,000 years old or older. This is significantly older than expected based on the scarp morphology, but the well-cemented soil and arid climate may have preserved the scarp and protected it from erosion. IGS also dated a younger unfaulted alluvial fan deposit that covers a younger strand of the fault providing a minimum age for the most recent earthquake. Soil samples collected for optically stimulated luminescence (OSL) dating yielded an age of ~15,400 years old.

Given these ages, it is estimated that the main Halfway Gulch range front fault was active ~130,000 years ago or older and that smaller fault strands have been active as recently as ~15,000 years ago. This yields very low slip rates of 0.1 mm/yr or less for the Halfway Gulch fault. The locus of fault activity may have moved further north into the basin on the Water Tank fault zone, which may have been active as recently as ~5,000 years ago. It is not clear if the Halfway Gulch fault poses a significant seismic hazard to the region since low slip rate faults can still produce damaging earthquakes. However, the results of this investigation suggest that the Halfway Gulch fault is less active than its youthful appearance implies.
Geothermal energy is a valuable resource in Idaho and remains an essential player in the future of Idaho’s infrastructure. The Innovative Geothermal Exploration through Novel Investigations of Undiscovered Systems (INGENIOUS) project is a multi-faceted program funded by the U.S. Department of Energy to accelerate discoveries of new geothermal systems within the Great Basin while reducing exploration risk. While many geothermal systems are related to shallow magmatic heat sources, the systems of the Great Basin are largely fault controlled. Moreover, many of these potential systems may be blind or hidden because they don’t manifest surficial features like geysers or sinter deposits. As such, a crucial component of this investigation is identifying and cataloging favorable structural settings (FSS), which are defined by the orientation, distribution, and patterns within a system of young normal faults. The figure (top-right) shows a beautiful example of a FSS northwest of Grasmere, Idaho. Documenting these fault complexes and incorporating other data sets, such as shallow temperature readings, geophysics, and remote sensing data, allows geologists to better target potential geothermal systems.

Researchers from the IGS spent part of this past winter identifying and evaluating 141 FSS within the Great Basin portion of Idaho (essentially, all of Idaho south of the Snake River Plain). The IGS collaborates with researchers from the Great Basin Center for Geothermal Energy and neighboring state geological surveys of Nevada and Utah to advance the mission of the INGENIOUS program. The INGENIOUS team will incorporate our new catalogue of FSS into 3D models and prospect-favorability software tools. These innovative products will aid in improving exploration workflows, conceptual understandings, and geothermal viability in Idaho.

A) LiDAR-derived slopeshade image of a favorable structural setting (FSS) northwest of Grasmere, Idaho. B) Annotated version of the image in 1A, outlining a complex normal fault arrangement interpreted as a ‘breached relay-ramp accommodation zone.’ The green-line polygon defines the FSS footprint, while the thicker blue lines denote normal fault traces — the first-order fault has the bar-and-ball symbol on the downthrown block.

Favorable structural settings working group during a collaborative meeting in Reno, Nevada.
FY 2023 saw continued geologic mapping and research efforts in the Idaho cobalt belt and initiation of work in the Mineral Hill REE district northwest of Salmon. This work is driven by the national need for critical minerals for which the U.S. is currently heavily reliant on markets dominated by foreign countries. The USGS has released and updates a list of commodities deemed critical to the national economy and security and manages a program aimed at the identification of critical mineral resources – Earth MRI. IGS is working with the Earth MRI program to identify critical mineral resources in the cobalt belt of eastern Idaho, a northwest-trending zone of cobalt, copper, gold, and anomalous rare-earth elements west of Salmon. IGS aims to provide the public with data from the cobalt belt gained through geologic mapping, field reconnaissance sampling of rocks and stream sediments, mineralogic characterization, and data preservation methods, such as digitizing data from historic geochemical surveys of the region.

New in FY 2023 was the initiation of the Mineral Hill REE project northeast of the Idaho cobalt belt. Similar to the Cobalt Belt project, geologic mapping, geochemical sampling, and geochronologic work will be completed during a multi-year effort. Prospects there are part of a larger belt of critical mineral deposits, including associated carbonatite, extending from Lemhi Pass area southeast of Salmon, north-northwest along the Idaho-Montana border and into Canada.

The Idaho cobalt belt consists of strata-bound copper-cobalt deposits that have a complex history. In contrast, the Mineral Hill REE district is hosted by Proterozoic dioritic and granitic rocks that contain small carbonatite lenses. An important contribution by the IGS is the collection of surface measurements of magnetic susceptibility (magnetite content) and uranium-thorium-potassium content to better understand the distribution, age, and controls of mineralization in both areas. These efforts will also help with interpretation of the cooperative USGS-Industry aeromagnetic and radiometric survey in this area that was released in 2022.
Notable Outcomes

- Completed the second phase of field work for USGS Earth MRI (critical minerals) project in the Idaho cobalt belt by mapping the Blackbird Creek and Opal Lake quadrangles at 1:24,000 scale.

- Hosted the second Salmon Field Forum, bringing together over 25 representatives from industry, IGS, USGS, and various academic institutions for presentations and field trips to the Pope-Shenon copper property and the Iron Creek copper-cobalt property.

- Continued to take outcrop magnetic susceptibility measurements to help with the interpretation of the 2021 airborne magnetic data. Data gathered to date was released in March 2023 as a Digital Analytical Data publication (DAD-20) consisting of over 2,900 measurements in the Salmon area and the Idaho panhandle.

- Ramped up efforts to collect K-U-Th concentration data using a hand-held gamma-ray spectrometer.

- Continued efforts to collect mineralized and unmineralized rock samples to provide baseline compositional data for copper-cobalt concentrations.

- Hired a project geologist for the Mineral Hill Project and commenced field work in June 2023.
Iron Creek Magnetite Study

The Iron Creek Cu-Co deposit is at the southeast end of the Idaho cobalt belt in Lemhi County and was being explored by Electra Battery Materials in 2022-2023. The Iron Creek deposit and its host rocks contain enigmatic, locally abundant magnetite, an iron oxide mineral; the copper and cobalt are found in the sulfide minerals, chalcopyrite and cobalt-bearing pyrite. This project has used microscope examinations and LA-ICPMS (laser ablation inductively coupled plasma mass spectrometer) analyses of magnetite grains in barren and mineralized strata at Iron Creek with the goal of understanding the origin of the magnetite and whether it is related to the Cu-Co mineralization. The textures seen in the samples suggest that much of the magnetite originated in the ancient Belt Supergroup sediments as either detrital grains or from old hydrothermal spring vents. Textures like the magnetite-bearing ore breccia in the photo (right) record subsequent hydrothermal, structural and metamorphic recrystallization of the magnetite and ore metals. A newly obtained radiometric 40Ar/39Ar age of approximately 900 Ma on biotite in a vein associated with the Cu-Co ore indicates that the mineralization had formed and was metamorphosed during Precambrian time.

Interpretation and more analyses are ongoing. Trace element chemistry of the Iron Creek magnetite grains is being compared to that of magnetite from other ore deposits described in the literature. Concentration graphs of trace elements such as Al, Mn, Ti, and V in magnetite can be used to distinguish certain mineral deposit types. Iron Creek magnetites are relatively low in their trace element abundance, but preliminary concentration data plots within proposed fields for hydrothermal deposits, banded iron formations and iron oxide-copper-gold deposits (IOCG). One proposed model for the cobalt belt is a variant of an IOCG deposit with iron oxide and copper mineralization presumably related to the 1.37 Ga megacrystic granite plutons and mafic intrusions in the region. However, the magnetite is not always associated with either copper or with the cobalt. Other genetic models for the cobalt mineralization involve circulation of basin brines during or shortly after sedimentation in a rift setting. The current complex distribution of copper and cobalt mineralization is due to the superposition of more than a single genetic system and multiple, later geologic events.

Cobalt-bearing pyrite (brassy colored grains) and magnetite (black) in the matrix of a breccia with quartzite clasts. From drill core at the Ruby zone, Iron Creek deposit, Lemhi County.
The Don Adair Collection

Don Adair, an exploration geologist that worked extensively in Idaho, generously donated his personal files to the IGS’ Data Preservation effort in 2022. This voluminous collection includes maps, correspondence, field notes, reports, and research materials, and represents the work of a respected Idaho geologist over decades. IGS is grateful to Don for his contribution and his trust in the Survey to curate an invaluable portion of his legacy.

Though IGS has made significant progress sorting, cataloging, scanning, and providing public access to Don’s data, only about 1/5 of approximately 40 cubic feet of material has been explored. And aside from what one might expect from an exploration geologist, there are several considerations for this collection that underscore its value as a priority data preservation effort.

1. Adair’s curiosity and meticulous attention to detail is the cornerstone of the value of these data. Importantly, his background research materials and notes in preparation for fieldwork were contributed. These include many sources including notes on verbal communications, newspaper clippings, shareholder and investment pamphlets, journal articles, and publication excerpts. Also included are sources from past exploration efforts, development, and production data acquired from past operators and other parties along with detailed mineral ownership summaries, claim maps, surveys, and plats. All of this is information involving significant effort and expense to acquire. Lastly, there are ‘whimsical’ data that speak to his relentless curiosity, such as meteor fallings and findings that extend well beyond Idaho.

2. The care Adair has taken in cartography and relating analytical data spatially is remarkable. Details can include surface maps for drill hole locations with annotations and original assay documents that inform commodity values at depth. But it seems that Adair approached his work as a scientist funded by mining interests rather than a contractor noting geology. His observations and data will undoubtably support future academic research.

3. Adair comes across as practical and direct, to the point of possessing a singular matter-of-fact wit. His tolerance for foolhardiness is very low. He pulls no punches and commits these sentiments to writing. His benefactors are in no way exempt from such scrutiny. These have been a source of amusement while processing the collections, but also lend to the respect for not only the data, but for Adair.
Magmatic-driven Hydrocarbon Generation Beneath the Western Snake River Plain of Southwestern Idaho

Crude oil and natural gas are typically generated within buried organic-rich sediments over long geological timescales. However, these processes can be accelerated when sediments are exposed to magmatic intrusions related to nearby volcanic activity. Research at the IGS is attempting to evaluate the role of igneous intrusions in the generation of hydrocarbons from strata that lie beneath the western Snake River Plain (WSRP) of southwestern Idaho. Evidence of magmatic-generated hydrocarbons from the WSRP includes: a) A close spatial relationship between intrusions and hydrocarbon occurrences; b) Thermal alteration of organic matter from sediments that lie adjacent to intrusive bodies; and c) Geochemical markers from produced hydrocarbons that show a level of maturity beyond that expected from the regional geothermal gradient.

Due to their acoustic properties, igneous intrusions are easily visible in seismic surveys. An interpreted seismic line from the WSRP near the Harmon and Willow Fields is displayed in the figure (bottom right). Nearby oil and gas accumulations occur in a faulted sandstone interval (indicated by the red hatched region in the figure), capped by impermeable mudstones of the upper Chalk Hills Formation. These mudstones act as a seal, limiting the upward migration of hydrocarbons. Notable in the seismic are the large number of dish-shaped bodies or sills (indicated by green fills) that intrude the underlying Poison Creek Formation, a unit known to contain organic-rich sediments. Sediments surrounding the intrusions undergo chemical changes due to the high temperatures and pressures associated with the injection of molten magma—a process referred to as contact metamorphism. The regions that have been altered are known as contact aureoles or baked zones. The lateral extent of these zones depends on the volume of intruding magma and its temperature. The impact of contact metamorphism on organic matter involves its conversion into fluid hydrocarbons, which, if produced in sufficient quantities, can migrate out of the baked zone. Additionally, a residue referred to as pyrobitumen is left behind, which is significant as it indicates the conversion of organic matter to hydrocarbons has taken place.

Understanding magmatic-driven hydrocarbon generation contributes to exploration endeavors by pinpointing potential hydrocarbon-rich regions, unraveling underlying geological processes, and enabling well-informed decisions in petroleum exploration. This comprehension is pivotal in mitigating exploration risks and enhancing the likelihood of unearthing economically viable hydrocarbon reserves.

Idaho’s producing oil and gas fields, informally referred to as Willow, Harmon, and Hamilton, after the sand intervals from which they produce, occur beneath the western Snake River Plain of southwestern Idaho.
Idaho Seismic Network

Idaho is earthquake country! The M6.5 Stanley earthquake of March 2020 and the currently ongoing aftershock sequence is only the most recent reminder that the gorgeous and rugged landscape that characterizes the state is in fact underlined (and shaped) by active tectonic processes which occasionally manifest themselves through dramatic events like earthquakes.

Yet Idaho has never had a state-operated network of instruments capable of detecting earthquakes occurring within the state (and beyond), and all monitoring activities have been delegated to the goodwill of neighboring states and federal agencies. Nonetheless, the lack of proper instrumentation has hindered the ability of precisely recording, locating, and understanding seismic processes behind the many earthquake occurrences creating a lack of knowledge that affects not only the safety, security, and resilience of Idaho’s citizens and infrastructure, but also has direct influence on Idaho’s economy and the ability to better understand what’s beneath our feet. In order to put an end to this long-lasting data gap, and in full observance of its statewide data collection mandate, IGS has dedicated, since mid-2020, substantial personnel and financial resources to the acquisition, construction, deployment, and operation of the Idaho Seismic Network, which currently consists of five broadband seismometers spread across central Idaho with a few more instruments awaiting siting and permitting to hopefully be deployed next year.

Construction and installation phases of two seismometers of the Idaho Seismic Network: Taylor Ranch station (WW.TYLR - left) and Big Cottonwood Creek station (WW.CTNW - right). Data transmission is secured through either satellite communications or cellular modem.
Data from these instruments are collected in near-real time and delivered through the IGS server to a global data repository hosted by the EarthScope consortium (formerly IRIS) for the benefit of the global scientific community. While IGS staff is not yet geared for performing data analysis on its own (pending a dedicated funded position for a state seismologist), the data collected have been instrumental in detecting and locating hundreds of new earthquakes by both the USGS and, even more, by Idaho’s closest collaborators at the Earthquake Studies Office of the Montana Bureau of Mines and Geology (MBMG).

As often happens when searching in places never looked at before, interesting findings appear, and more is being learned with every new instrument that IGS deploys. As an example from IGS’ most recently installed instrument, here below a spectrogram from about 07:30 to 09:30 UTC on October 10, 2023, just a couple weeks after its deployment in the Red Fish Lake area south of Stanley, Idaho. It recorded approximately 45 (small) earthquakes in less than 2 hours, with a burst of rapid-fire events visible in the center-right part of the figure. This is an unusual behavior 3.5 years into an aftershock sequence when activity is expected to die down, but perhaps this sort of behavior has been going on for months or even years and only now is being detected.

IGS is committed to continue building capabilities in this area and to grow the Idaho Seismic Network to cover the entire state with at least minimal instrument density. This is not an easy task which IGS has so far supported internally as an unfunded effort. IGS is fortunate for the support of dedicated scientists and colleagues that have volunteered their time and expertise to bring the IGS skillset up to the task (Ken Sprenke, Bob Hammond, Mike Stickney, and Josh Stachnik, among others). IGS is grateful for their support and for the kind generosity of the many landowners who are hosting these instruments.

For more information on the Idaho Seismic Network, and to access data, please refer to [https://doi.org/10.7914/SN/WW](https://doi.org/10.7914/SN/WW).

The spectrogram above shows a burst of small quakes which show up as vertical red slashes that extend all the way to the bottom of the plot. Courtesy of Mike Stickney, Earthquake Studies Office, MBMG.

<table>
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<tr>
<th>Station Code</th>
<th>Station Name</th>
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<tr>
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<td>CTNW</td>
<td>Big Cottonwood Creek</td>
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<td>IRMA</td>
<td>Idaho Rocky Mountain Ranch</td>
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<td>TBRD</td>
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<td>TYLR</td>
<td>Taylor Ranch Idaho</td>
<td>45.101927</td>
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</table>

Location map of the Idaho Seismic Network as of October 2023. The table lists the five active stations and their coordinates (datum WGS84).
# PEOPLE

## Idaho Geological Survey Staff

### Moscow Office
University of Idaho  
Morrill Hall, Third Floor  
875 Perimeter Drive MS 3014  
Moscow, ID 83844-3014  
208-885-7991

### Boise Office
Idaho Water Center  
Suite 201  
322 E. Front Street  
Boise, ID 83702  
208-332-4420

### Administration
- Claudio Berti .......................................................... Director and State Geologist, Moscow
- John R. Brabb ..................................................... Finance and Operations Manager, Moscow
- Nathan Hopkins ..................................................... Digital Mapping and GIS Lab Manager, Moscow
- Kristen Pekas .......................................................... Management Assistant, Moscow

### Research, Full-Time
- Mark Barton .......................................................... Senior Petroleum Geologist, Boise
- Alexis Clark .......................................................... Hydrogeologist, Boise
- Russell Di Fiori ..................................................... Senior Geologist, Moscow
- Dennis M. Feeney ..................................................... Senior Geologist, Moscow
- Jacob Eldredge ..................................................... Data Preservation Specialist, Moscow
- Scott Gifford .......................................................... Project Geologist, Boise
- Virginia S. Gillerman ................................................ Research Geologist, Boise
- Liam D. Knudsen ..................................................... Junior Geologist, Moscow
- Reed S. Lewis ......................................................... Research Geologist, Moscow
- Zach Lifton .......................................................... Hazards Geologist, Boise
- Jonathan E. Sandquist ................................................ Digital Cartographer, Moscow
- Joel Schiffer .......................................................... Project Geologist, Moscow
- Cody J. Steven ......................................................... Postdoctoral Researcher, Moscow
- Jesslyn Starnes ....................................................... Data Preservation Specialist, Moscow
- Christopher A. Tate ................................................ Mines and Prospects Database Manager, Moscow
- Linda Tedrow .......................................................... GIS Analyst, Moscow
- Mary Tkach .......................................................... Junior Geologist, Moscow
- David Vohra .......................................................... GIS Analyst, Moscow

### Research and Support, Part-Time
- Jean Allen .......................................................... Research Support
- Ryan B. Anderson .................................................... Geologist
- Russell F. Burmester ................................................ Geologist
- Kendra Beardsley ................................................... Research Support
- Nicole Guthrie ........................................................ Research Support
- Madeline Murchland ................................................ Geologist
- D. Kate Schalck ...................................................... Geologic Editor
- Jennifer Rangel ........................................................ Research Support
- Cole Ritts ............................................................. Research Support
- Keegan L. Schmidt .................................................. Geologist
- David E. Stewart ..................................................... Geologist
Idaho Geological Survey Advisory Board

Ex Officio: Claudio Berti – Chair
Director and State Geologist, Idaho Geological Survey

Susan Cleverly
Mitigation Section Chief, Idaho Office of Emergency Management

Benjamin Crosby and Glenn Thackray
Chair, Department of Geosciences, Idaho State University

Chris Dail
Exploration Manager, Perpetua Resources Idaho, Inc.

David Hawk
Representative, Office of the Governor

Jim McNamara and Dorsey Wanless
Chair, Department of Geological Sciences, Boise State University

Mick Thomas
Oil and Gas Division Administrator, Idaho Department of Lands

Alistair Smith
Interim Department Chair, Department of Earth and Spatial Sciences, University of Idaho

Alyssa Veatch
President, Idaho Association of Professional Geologists
Environmental Permitting Specialist, DeLamar Mining Co.

Idaho Geological Mapping Advisory Committee

Dale Kerner – Chair
Permitting Manager, Perpetua Resources Idaho, Inc.

Katy Bergholm
Regional Administrator, Pocatello Regional Office, Idaho Department of Environmental Quality

Dominique Brough
Geologist, Caribou-Targhee National Forests

Shawn Enright
District Geologist, Idaho Transportation Department

David Hawk
IGS Advisory Board, E2A Energy Analysis and Answers

Rachel Hunt
Project Geologist, Cornforth Consultants

Josh Johnson
Senior Conservation Associate, Idaho Conservation League

Mark Kimsey
Research Associate Professor, Forest Resources Director, Intermountain Forestry Cooperative, University of Idaho

Joe Larsen
Geologist, Mining Law Program Lead, Bureau of Land Management

Sean Long
Associate Professor, Earth Sciences, Washington State University

Michael McVay
Water Resources Engineer, Idaho Department of Water Resources

Robert Morgan
VP Exploration, Idaho Strategic Resources, Inc.

Robert Mullener
Permitting Manager, DeLamar Mining Co.

David Pearson
Associate Professor, Geosciences, Idaho State University

Dave Schwarz
Resource Geologist, Idaho Department of Lands

Lydia M. Staisch

Richard Stover
Administrator, Idaho Office of Energy and Mineral Resources
PARTNERSHIPS

Funding Partners

Idaho Department of Commerce
IGEM
Idaho Department of Lands
Abandoned Mine Lands
Idaho Department of Water Resources
Raft River Valley

Electra Battery Materials Corporation
Petrochemical Study of Magnetite in the Iron Creek Co-Cu Area
University of Nevada, Reno
INGENIOUS project
U.S. Geological Survey
STATEMAP | Data Preservation | NEHRP | Earth MRI

Collaborators

American Exploration and Mining Association
American Geophysical Union
American Geosciences Institute
American Ground Water Trust
American Water Resources Association, Idaho State Section
Association of American State Geologists
Basin and Range Earthquake Working Group
Belt Association
BETA Analytics
BGC Engineering
Boise State University
Brigham Young University-Idaho
British Columbia Geological Survey
Bunker Hill Mining Corporation
California Geological Survey
Center for Human Evolution (CENIEH)
Center for Advanced Energy Studies
College of Idaho
Colorado School of Mines
Consortium of Regional Seismic Networks
Federal Emergency Management Agency
Electra Battery Materials
EarthScope Consortium
Frontier Precision
Geological Society of America
Geological Society of Nevada
Geomark Laboratories
Governor’s Office, State of Idaho
Great Basin Center for Geothermal Energy
Idaho Department of Commerce
Idaho Department of Environmental Quality
Idaho Department of Lands
Idaho Department of Water Resources
Idaho Geospatial Office
Idaho Ground Water Monitoring Technical Committee
Idaho Historical Society
Idaho Master Naturalists
Idaho Mining Association
Idaho Museum of Mining and Geology
Idaho National Lab
Idaho Office of Emergency Management
Idaho Office of Energy and Mineral Resources
Idaho Oil and Gas Conservation Commission
Idaho State University
Idaho Transportation Department
Indiana State University
Idaho Strategic Resources
Integra Resources
Intermountain Forestry Cooperative
Instrumental Software Technology Inc.
Lehigh University
Lettis Consultants International
Lewis-Clark State College
Midas Gold Corporation - change to Perpetua Resources
Montana Bureau of Mines and Geology
Nanometrics
National Academy of Science
Nevada Bureau of Mines and Geology
Nev-Gold Inc.
Northwest Knowledge Network
Oregon Department of Geology and Mineral Industries
Oregon State University- College of Earth, Ocean, and Atmospheric Sciences
Orma J. Smith Museum of Natural History
PetroStrat Services
Revival Gold
Snake River Oil and Gas
Schlumberger Petroleum Services
Society of Mining Engineers, Boise Section
Tobacco Root Geological Society
U.S. Bureau of Land Management
U.S. Forest Service
U.S. Geological Survey–Cascade Volcano Observatory
U.S. Geological Survey–Geologic Hazards Science Center
U.S. Geological Survey– Minerals Program
U.S. Geological Survey–NEHRP
U.S. Geological Survey– Water Resources Division
U.S. Geological Survey–Data Preservation
U.S. Geological Survey–Earth-MRI Program
U.S. Geological Survey–NCGMP
University of Alaska, Fairbanks
University of Idaho
University of Massachusetts Lowell
University of Nevada, Reno
Utah Geological Survey
Washington Geological Survey
Washington State University
Western Governors Association
Western Colorado University
Western States Seismic Policy Council
Western Washington University
Wyoming Geological Survey
Yellowstone Volcano Observatory
FINANCIALS

FY 2023 Budget Table

<table>
<thead>
<tr>
<th>Category</th>
<th>Beginning Balance</th>
<th>Income or Appropriations</th>
<th>Actual</th>
<th>Expense</th>
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<td>$2,266,754.28</td>
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</table>

Trends in Expenditures

FY 2024 Budget Request

The FY 2024 budget request was limited to a 3.0% ($36,906) increase per the Governor’s Office directives. After working with the University and State Board of Education on several rounds of refinements and changes to a larger initial request, the final recommended and appropriated budget was $1,294,000. IGS was allocated $1,255,300 in personnel costs, which saw a reduction of $1,200 in variable benefit costs, an increase of $15,400 in health benefit costs, an increase of $12,400 in employee retention (all combined to meet the 3.0%/$36,906 limit), and $41,000 (~$29,286 in salary and $11,714 in benefits) for change in employee compensation (CEC), as recommended by the Governor. Operating Expense (OE) allocation remained at the FY 2023 level of $38,700. Due to the 3.0% increase limitation, IGS did not request any one-time Capital Outlay (CO) funding. The CEC and employee retention increases were implemented by IGS at or exceeding the recommended rates by both the Governor’s Office and the University. An estimated 43% of the awarded CEC increase and 75% of the OE and CO expenses are projected to be generated by grant-funded salary and benefit savings. The University of Idaho Office of Research and Economic Development allowed projected overspending as backed up by expected grant funds.
Sources of Funding

Since its release in 2012, *Geologic Map of Idaho* (M-9) has continued to be the best-selling IGS publication.

<table>
<thead>
<tr>
<th>Publication Type</th>
<th>FY 2018</th>
<th>FY 2019</th>
<th>FY 2020</th>
<th>FY 2021</th>
<th>FY 2022</th>
<th>FY 2023</th>
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FY 2023 Annual Report 20
PUBLICATIONS AND ACTIVITIES

Publications


Abstracts


Reports


Grants and Contracts


Development of Idaho-sourced Rare Earth Elements Drilling and Extraction: Award to University of Idaho: A. Mirkouei, PI, with Idaho Geological Survey co-Pls, C. Berti and V. Gillerman (Idaho Department of Commerce IGEM Program, March 2022 – December, 2023, IGS portion is $ 80,491 of UI award of $ 348,241).

Geologic Mapping in the Idaho Cobalt Belt II: R.S. Lewis (U.S. Geological Survey Earth-MRI Program, September 2021-August 2023, $100,000).


Idaho Department of Lands Abandoned Mine Lands Project, Task 6: R.S. Lewis (Idaho Department of Lands, April 2021-March 2023, $169,445).
Idaho Department of Lands Abandoned Mine Lands Project, Task 7: R.S. Lewis (Idaho Department of Lands, April 2023-March 2025, $218,840).


Petrochemical Study of Magnetite in the Iron Creek Co-Cu Area, Lemhi County: V.S. Gillerman (Electra Battery Materials/First Cobalt, December 1, 2021 – December 31, 2023 ($ 16,459).


USGS Earth MRI Western Geochemical Data Collection Project for the Western Phosphate Field: Mark D. Barton (U.S. Geological Survey Earth-MRI Program, September 2022-August 2025, $525,000).

Presentations


Earth MRI Efforts in the Idaho Cobalt Belt, by Reed S. Lewis: USGS Earth-MRI Virtual Meeting, Online, October 2022.


Geothermal Opportunities Across the US. Introduction to the Geothermal Breakout Session, by Claudio Berti: AASG annual meeting, Glenwood Springs, Colorado, June 2023.


Geothermal Resource Assessment, Challenges and Opportunities in the Western US, by Claudio Berti: Western Governors Association annual meeting, Boulder, Colorado, June 2023.


State Earthquake Clearinghouse, by Zachery M. Lifton: Basin and Range Earthquake Summit, Salt Lake City, Utah, October 2022.


Education and Outreach Activities


Co-leaders, Idaho Naturalists Field Trip, Sandpoint, Idaho September (R.V. Di Fiori, R.S. Lewis).

Co-leader, University of Idaho Soils/Intermountain Tree Cooperative Field Trip, North Idaho, Idaho, September 9-11, 2022 (R.V. Di Fiori).

Distributors, American Geosciences Institute Earth Science Week Toolkits, September 2022 (D.M. Feeney and K.M. Pekas).
Leader, Iron Creek to Williams Creek Summit Field Trip, IGS Salmon Field Forum, Salmon, Idaho, September 2022 (R.S. Lewis).
Organizer, IGS Salmon Field Forum, Salmon, Idaho, September 2022 (R.S. Lewis).
Presenter, Lena Whitmore elementary School, Moscow, Idaho, 2023 (C. Berti).
Presenter, Moscow Boy Scout Troop, Moscow, Idaho, 2023 (C. Berti).
Volunteer, University of Idaho AVID STEM Days, Boise, Idaho, March 2023 (S. Gifford).

**Education and Outreach Presentations**


*Why is Boise Idaho good for geothermal resources?*, by Alexis Clark: Boise State University Geothermal CE-EC Course, Boise, Idaho, September 2022.

**Media Interviews**


**Web Products**


Oil & Gas Web Application, by Jacob A. Eldredge, Christopher A. Tate, and Dustin Thomas: Idaho Geological Survey Web Application, [https://idahogeology.org/WebMap/](https://idahogeology.org/WebMap/), April 2023.

**Operational Improvements**

Acquisition of Don Adair Mining File Collection, by Virginia S. Gillerman, June 2022.

Data Entry Workflow Student Handbook, by Jacob A. Eldredge and Christopher A. Tate, June 2023.


IGS GeMS ArcMap Digitizing Template, by Nathan Hopkins, December 2022.


IGS Mines and Prospects Database Redesign, Refactor, and Data Normalization, by Christopher A. Tate and Jacob A. Eldredge, May 2023.


IGS Oil and Gas Database Update, by Jacob A. Eldredge, Christopher A. Tate, and Mark D. Barton, May 2023.

IGS Young Fault Database Update for Southwest Idaho, Owyhee County, by Russ Di Fiori, January 2023.

**Graduate Thesis Committees**

Cameron Wallenbrock, M.S. Geology, Washington State University (R.S. Lewis).

Dana Drinkall, M.S. Geology, Idaho State University (Z.M. Lifton).

Isabelle Rein, M.S. Geology, Washington State University (R.S. Lewis).

John Murphy, M.S. Geology, Washington State University (R.S. Lewis).

Liam D. Knudsen, M.S. Geology, University of Idaho (R.S. Lewis)

**Professional Activities**

Affiliate Faculty, Boise State University (V.S. Gillerman).

Affiliate Faculty, University of Idaho (M.D. Barton, C. Berti, R.V. Di Fiori, V.S. Gillerman, R.S. Lewis).

Affiliate Faculty, Washington State University (R.S. Lewis).
Co-convener, Basin and Range Earthquake Summit Geology Session (Z.M. Lifton)
Fellow, Society of Economic Geologists (V.S. Gillerman).
Member, American Exploration and Mining Association (V.S. Gillerman, R.S. Lewis).
Member, American Geophysical Union (C. Berti, R.V. Di Fiori).
Member, American Water Resources Association (A.L. Clark).
Member, Association of American State Geologists (C. Berti).
Member, Basin and Range Province Earthquake Working Group (Z.M. Lifton).
Member, Big Lost River Modeling Technical Advisory Committee (A.L. Clark).
Member, Collaborative Database Effort For Geology (CDEFG) Working Group (N. Hopkins, L. Tedrow).
Member, Consortium of Regional Seismic Networks (Z.M. Lifton).
Member, Eastern Snake Hydrologic Modeling Committee (A.L. Clark).
Member, Geological Society of America (C. Berti, R.V. Di Fiori, V.S. Gillerman, N. Hopkins, R.S. Lewis, Z.M. Lifton, C.A. Tate).
Member, Geological Society of Nevada (V.S. Gillerman).
Member, Ground Water Monitoring Technical Committee (A.L. Clark).
Member, Idaho LiDAR Consortium (Z.M. Lifton).
Member, Incorporated Research Institutions for Seismology (IRIS) Portable Array Seismic Studies of the Continental Lithosphere (PASSCAL) (C. Berti).
Member, National Ground Water Association (A.L. Clark).
Member, Society for Mining, Metallurgy, and Exploration and Boise Section of Society for Mining, Metallurgy, and Exploration (V.S. Gillerman).
Member, Tobacco Root Geological Society (R.V. Di Fiori).
Member, Treasure Valley Modeling Technical Advisory Committee (A.L. Clark).
Member, Yellowstone Volcano Observatory (Z.M. Lifton).
MSHA certification (S. Gifford).
Oregon Registered Professional Geologist (A.L. Clark).
Participant, American Exploration and Mining Association Annual Convention, Reno, Nevada, December 2022 (V.S. Gillerman).
Participant, Geologic Mapping Forum, Online, Periodic (N. Hopkins).

Participant, Geological Society of Nevada Symposium, Reno, May 2023 (R.S. Lewis).

Participant, Idaho Mining Conference, Boise, October 2022 (S. Gifford, V.S. Gillerman, R.S. Lewis).


Participant, LiDAR Applications and Spatial Analysis Workshop, Idaho State University, Online, January 2023 (J.A. Eldredge).


Participant, Tobacco Root Geological Society Annual Field Conference, Wenatchee, Washington, July 2022 (R.S. Lewis)


Participant, Working with LiDAR in ArcGIS Pro Workshop, Idaho State University, Online, January 2023 (J.A. Eldredge).


Representative, UNAVCO WinSAR Consortium (Z.M. Lifton).

Reviewer, National Park Service Grant Proposal (Z.M. Lifton).


Washington Registered Geologist with Hydrogeologist Specialty (A.L. Clark).

Washington Registered Professional Geologist (Z.M. Lifton).

Wilderness First Responder, National Outdoor Leadership School (NOLS) (Z.M. Lifton).