compatible with the presence of a high-angle fault at the northern flank of Golden Rule Peak, coincident with the gravity gradient. Thus, the Golden Rule Peak lineament may represent a transverse structure, specifically, a transfer fault that formed during the linkage of the Salt Spring and Cyclopic Mine segments. However, much more work is necessary to establish the nature of the lineament and the relative timing of normal fault and strike-slip fault (if any) activity. Such a transverse zone, if it exists, would have served to partition strain within the variably extended crust of northwesternmost Arizona.

8-3 BTH 3 Siwiec, Benjamin R.

STRUCTURE AND METAMORPHISM IN THE NORTHERN HUALAPAI MOUNTAINS, ARIZONA: IMPLICATIONS FOR THE PALEOPROTEROZOIC TECTONICS OF THE SOUTHWESTERN UNITED STATES

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The boundary between the Mojave and Yavapai Proterozoic crustal provinces in Arizona has been the subject of much debate in recent years. A transition zone between the provinces with a well-defined eastern boundary has been proposed based on isotopic evidence. The western boundary of this zone is not as clear, but the Gneiss Canyon shear zone in the Lower Granite Gorge of the Grand Canyon has been proposed as a structural, metamorphic, and isotopic boundary. This zone has previously been projected 100 km southwest, through the northern Hualapai Mountains. New mapping in the northern Hualapai Mountains indicates that structures there are not compatible with those found in the Lower Granite Gorge. Rocks within the Gneiss Canyon shear zone in the Lower Granite Gorge are migmatitic and contain mylonitic LS fabrics with strong northwest-side-up kinematic indicators. Very few areas in the northern Hualapai Mountains are migmatitic and virtually no kinematic indicators are present, although some rocks are highly strained. Rocks in the northern Hualapai Mountains are dominantly S tectonites and commonly contain the regional, steeply dipping, northeast-striking D2 fabric, as well as some zones of the regional, moderately-to-steeply dipping, northwest-striking D1 fabric. The rocks in the northern Hualapai Mountains also contain evidence for a local(?) deformational fabric temporally between D1 and D2. This fabric is exposed as crenulation folding with fold axes dissimilar in orientation to both D1 and D2. Granulite-facies assemblages are present across the projected trace of the Gneiss Canyon shear zone, indicating the rocks in the northern Hualapai Mountains have a metamorphic history more similar to the Mojave province than the Yavapai province. This observation is compatible with recent metamorphic work in the Peacock Mountains and Pb isotopic studies that place the western margin of the transition zone significantly east of the Hualapai Mountains. Therefore, we propose that the Gneiss Canyon shear zone may project south from its exposure in the Grand Canyon rather than southwest.

8-4 BTH 4 Brumbaugh, David S.

PRELIMINARY ANALYSIS OF SEISMIC HAZARD TO FLAGSTAFF, ARIZONA, FROM THE LAKE MARY FAULT SYSTEM

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Flagstaff, Arizona is the largest urban center in northern Arizona with a population in excess of 50,000. Flagstaff was affected by ground shaking from three M>6.0 earthquakes in the early 1900's that caused minor damage. None of these tremors resulted in surface scarps. The Lake Mary fault system is the largest in the Flagstaff region with a total length of 40 kilometers and total normal offset of 122 meters. The magnitude of the Maximum Credible Earthquake(MCE)from total surface rupture is Mw6.9. Input of this event into HAZUS indicates potential for 11 fatalities, 530injuries and a total damage estimate of about 930 million dollars.

8-5 BTH 5 Hintze, Lehi F.

UTAH'S SOUTHERNMOST EOCENE VOLCANIC ROCKS IN THE LITTLE DRUM MOUNTAINS IN MILLARD COUNTY

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The Little Drum Mountains is a small northwest-trending basin-range about six miles at its widest and about 20 miles long. Its southeastern end lies about 20 miles west of Delta, Utah. Geologic mapping of two 1:24,000 quadrangles, Smelter Knolls West and Little Drum Pass, has shown the bedrock here to be layered Eocene volcanic rocks, broken by a few normal faults of small displacement, and tilted mostly westward at low angles. The rocks are about 6,400 feet (1,900m) thick and about evenly divided into three types: lava flows, volcanic conglomeratic debris flows, and ash-flow tuffs. $^{40}Ar/^{39}Ar$ dating reveals that these rocks were deposited between 39 and 35 million years ago. They represent distal deposits from the Drum and Keg Mountains volcanic centers to the north where associated ore deposits have been much studied. The Little Drums show no overt evidence of economic mineralization and so have been little prospected. The lava flows are mostly high K_2O andesites or pyroxene-rich latites. The ash-flow tuffs are generally rich in crystals and pumice. These deposits are the southernmost record of Eocene volcanic activity in Utah. They rest unconformably on folded Cambrian strata in the adjacent Drum Mountains north of the Little Drums.

8-6 BTH 6 Dickens, Keith E.

PETROLOGY OF MID-TERTIARY(?) VOLCANIC FLOWS IN THE NORTHERN RIO GRANDE RIFT, SALIDA, COLORADO

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A sequence of mafic-to-intermediate composition volcanic flows crops out in a paleochannel along the Arkansas River at Salida in central Colorado. The flows unconformably overlie the Wall Mountain Tuff (36.69 Ma) and Precambrian basement and may have developed either as late stage intermediate volcanism associated with the San Juan or Thirty-Nine-Mile volcanics or more likely, with early development of the northern Rio Grande Rift. Thirty-six samples were obtained from the Tenderfoot Hill region and several canyons to the south for analysis. Four major units were identified: 1)Clinopyroxene-bearing alkaline olivine basalt (AOB) is a 1,000 meter thick unit interbedded with thin layers of ash. The unit includes plag (4.5mm), pyroxene and olivine phenocrysts in an olivine, cpx, plag-rich groundmass. 2)Hypersthene-bearing trachyandesite (HBTA) found in the northern section of the study area, has phenocrysts of flow-oriented plag with clino- and orthopyroxene. 3)Hornblende-bearing trachyandesite (HTA) occurs in a small outcrop on the west side of Tenderfoot Hill and contains oxyhornblende, ortho- and clinopyroxene. 4)Pyroxene-bearing trachyandesite (PBTA) occurs as thick flows and laharic breccias. Rocks types are diverse, but contain plag, ortho- and clinopyroxene. Silica contents of the four units range from 51.9% (AOB) to 59.1% (PBTA). Based on geochemical graphs, AOB is a basaltic trachyandesite and the other units are trachyandesites. Except for AOB, they are tholeiitic. They are all very high in K2O (shoshonitic field) and Zr. Mg#s are highly evolved (~12-23). Ti and to a lesser degree Fe and Mg serve as excellent discriminators among the four flows. These flows all show similar REE patterns, ~300x enriched in LREE's with a slight negative Eu anomaly. Incompatible element plots show strong enrichment in K, Rb, Ba relative to MORB and a pronounced Nb-Ta trough. They are a good match for OIB or UCC. Tectonic discriminant diagrams are ambiguous; they plot as both rift and arc basalts. The geochemical data suggest the flows are early Rio Grande Rift volcanics that show crustal contamination (high K, Zr) but are derived from a mantle source. The Ta/Nb trough suggests that the source may be related to subduction-zone-modified lithosphere from the development of the Thirty-Nine Mile or San Juan Volcanic fields.

8-7 BTH 7 Stowell, Shara

VOLCANOLOGY OF THE NAVAJO LAKE VOLCANIC FIELD, SOUTHWESTERN UTAH

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The Navajo Lake volcanic field (NLVF) extends from Navajo Lake (NL), just east of Cedar City, Utah to Panguitch Lake (PL). The volcanic field is characterized by numerous basalt flows that erupted from more than 28 cinder cones. Many of the cones are aligned in a SE – NW direction. Three stages of basalt flows are recognized by mineralogy and morphology. Additionally, andesite occurs in the PL area. Although precise age of flows is unknown ($^{40}Ar/^{39}Ar$ dating is currently underway), many appear to be young (Recent). They are devoid of vegetation and have flow fronts 10 to 100 meters high. Flows erupted from the base and on the flanks of several cinder cones that are generally well covered by vegetation. In the PL area, the northernmost A'a flow is composed of a basal basalt flow and an upper andesite flow. These flows appear to have erupted from a common fissure system. The lava flow just north of Navajo Lake covers 15 km^2 and erupted from two vents on the west flank of a well vegetated cone. Aligned depressions in the western and central parts of NLVF probably reflect a network of lava tubes. Tertiary Brian Head and Claron formations and Isom formation pyroclastic flows underlie the NLVF. The volcanic rocks of the NLVF are calc-alkalic basalts and andesites. Stage 1, 2, and 3 basalts vary between 49 and 56% SiO_2, whereas andesite contains 57-61% SiO_2. Trace-element distribution diagrams show enrichment in Ba and Pb along with La and Ce compared to primitive mantle. These plots also show depletion in Nb and Ta suggesting a source in the lithospheric mantle. High Pb and K perhaps indicate crustal contamination. Initial $^{87}Sr/^{86}Sr$ of 13 samples are remarkably similar (0.704 +/- 0.0005). Tentatively, similar $^{87}Sr/^{86}Sr$ values may suggest that basalts and andesites of the NLVF are cogenetic.

8-8 BTH 8 Carlton, Cleet F.

TECHNICAL ASPECTS OF PHOTO-DOCUMENTATION AND CAPTURING AESTHETIC GEOLOGICAL SUBJECTS IN THE FIELD

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Photo-documentation and capturing the aesthetic features of geological subjects can be enhanced with attention to several basic rules of photographic technique. Major factors to be considered include lighting, color, and photographic composition.

Lighting of geological subjects for both documentation and aesthetic purposes includes the incident angle of sunlight (or other illumination source), brightness, and contrast. The angle of the light source is most important in how details on surfaces (e.g., exposed bedding planes, etching, sole marks) are captured. Brightness and contrast need to be adjusted to record pertinent details on film/digital file for photo-documentation. Brightness is typically adjusted through the combined reciprocal effect of aperture and exposure time, within the range of application of a particular film speed (or digital camera rating equivalence). The contrast between the lightest and darkest portions of the image is controlled by exposure settings and film type, and can be modified in post-processing through the dodging/burning method either in the darkroom or on the computer.

When color photography is employed, the purpose of attempting to capture "true" color or to represent the image with color enhancement should be established. A subject in the field has intrinsic color, which is modified by nature of the light illuminating it. Unless a physical sample of the subject is collected or a comparative reference (like a color chart) is used during the taking of the image, and the illuminating light can be recreated to compare the sample or reference to the image output, an interpretation will be required to estimate "true" color, irrespective of film type.

Photographic composition concerns the overall positioning of the elements in the image, including angle, distance, centering, and juxtaposition.

How lighting, color, and photographic composition can be best approached depends on the purpose and the final output of the image. The final output may be reflective media (paper, polyethylene), transparencies, and/or digital files. The final or maximum image/file size, and the technical quality requirements are key in determining the best method for obtaining the image.

8-9 BTH 9 Kenny, Ray

USING PHOTOGRAPHY AS AN EDUCATIONAL TOOL FOR TEACHING GEOLOGY TO UNDERGRADUATE STUDENTS

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The Geoscience Department at Fort Lewis College recently introduced non-traditional, mid-semester, "enrichment courses" combining field geology and photography. These courses were designed to stimulate experiential and interdisciplinary learning, and expose students to a wide variety of geologic and photographic environments. Discernable educational benefits from the geology-photography courses included: 1) mastery of abstract subject matter accomplished through photographic preparation and improved observational skills; 2) collaborative learning accomplished through interactive group dynamics; 3) increased interest in learning accomplished through "ownership" of a valued product; and, 4) fluent and rapid enhancement of formal classroom knowledge accomplished through activity-based and empowering pedagogy.

Prior educational and neurological research has shown that powerful, active learning experiences stimulate the brain resulting in improved memory and comprehension. The positive, unscripted and exciting "learning-centered" environment created by these new courses yielded memorable learning experiences that students have discussed throughout the entire semester! Assessment data suggest that the combined geology-photography courses successfully bridged academic goals and experiential needs of students.

Students researched specific geologic features, camped in areas with unique geology, and produced literary and photographic portfolios. Portfolio photographs were submitted to the American Geological Institute's National Photo Contest, and Ray Kenny's photograph was selected for use in the 2003 Earth Science Week brochures.