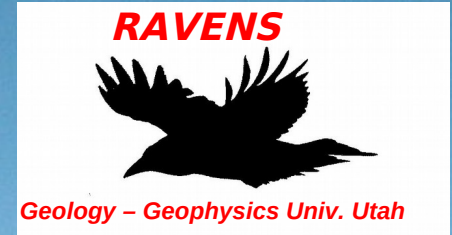


Structural and Alteration-Color Mapping of Navajo Sandstone (Example of RAVENS aircraft imaging)

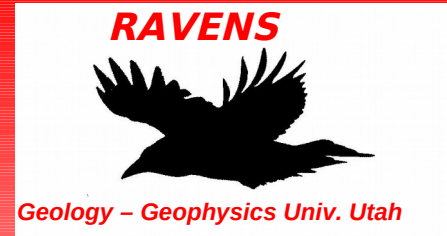


R.L. Bruhn
(in collaboration with S.R. Brown)

Geology and Geophysics,
University of Utah



Radio controlled aircraft, with digital still camera and in-flight video camera with transmitter. Video camera transmits to ground recorder and screen in real time. Hand held aircraft and camera control transmitter shown on left.



GOAL: Test of Radio-Controlled aircraft system using digital camera to detect and extract information concerning deformation bands and alteration in the Navajo Sandstone.

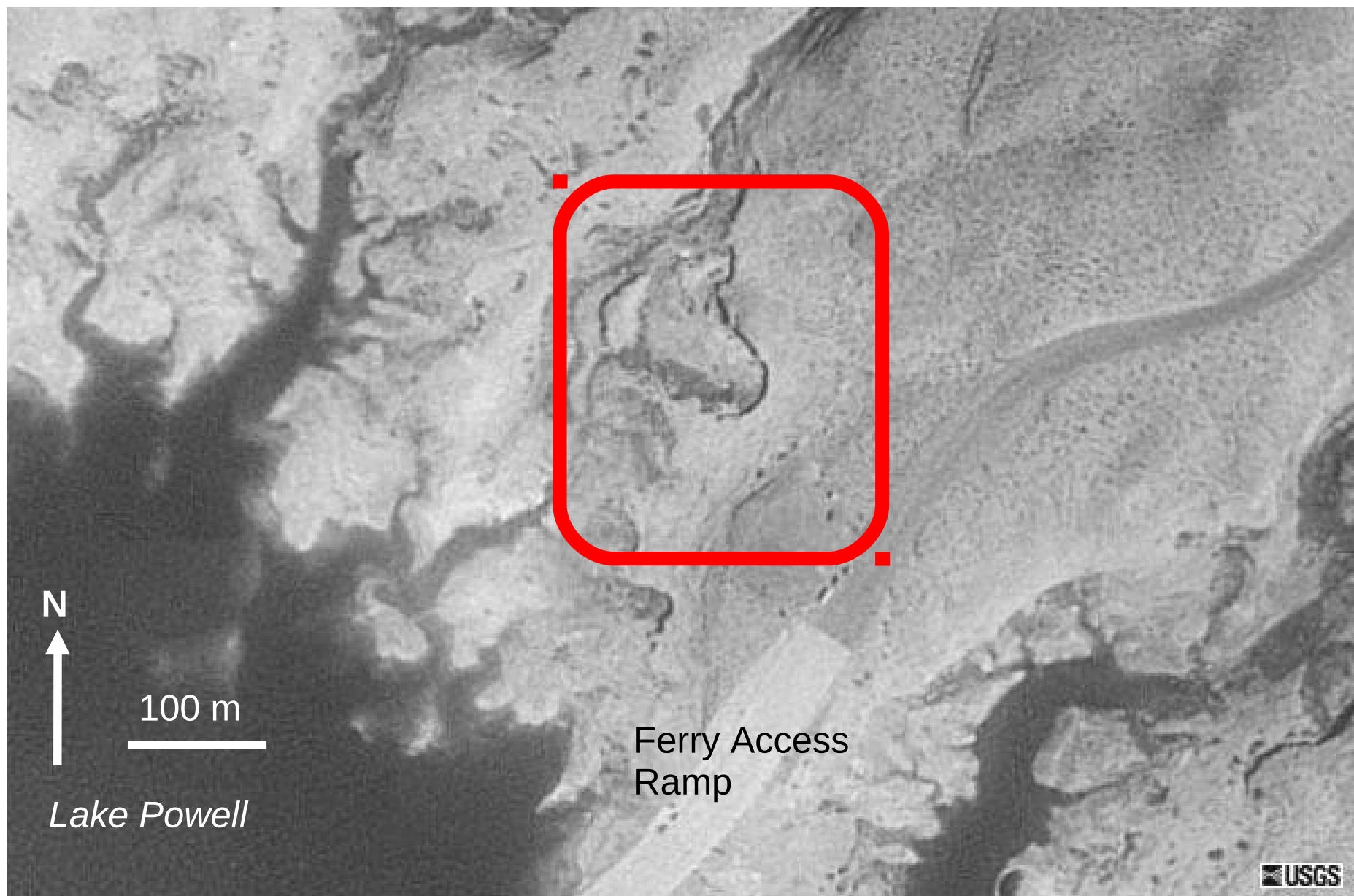
Location: Outcrop near the Ferry Landing at Bull Frog Marina, Lake Powell, UT on May 25, 2007. (UTM Zone 12 S, 524965 E, 4151774 N UTM Coordinates)

Equipment: Radio-controlled aircraft with 5 MegaPixel digital still camera and in-flight video camera that transmits to ground station. Electric motor powered with flight durations of about 15 minutes. Range and altitude capability approximately 1 km. Cameras may be rotated to obtain both vertical and oblique views.

Aircraft and Camera Operator: R.L. Bruhn, University of Utah

Image Processing: Images processed using decorrelation stretch to enhance subtle color variations in sandstone caused by diagenesis. Deformation band pattern (small faults) extracted using image segmentation and morphological operators.

Definition of Acronym: **RAVENS** – Radio-controlled Aerial Vehicles for Environmental Sensing.



Standard gray-scale vertical aerial photograph of the ferry landing area at Bull Frog Marina, Lake Powell, UT. Area shown in following slides is enclosed in red rectangle. RAVENS aircraft systems are designed to supplement this type of imaging by providing higher resolution and both vertical and oblique views.

Outcrop test area viewed from the ground. Note moderate color variation in the Navajo sandstone knob presumably caused by diagenesis and ground water flow.



RAVENS



Geology – Geophysics Univ. Utah

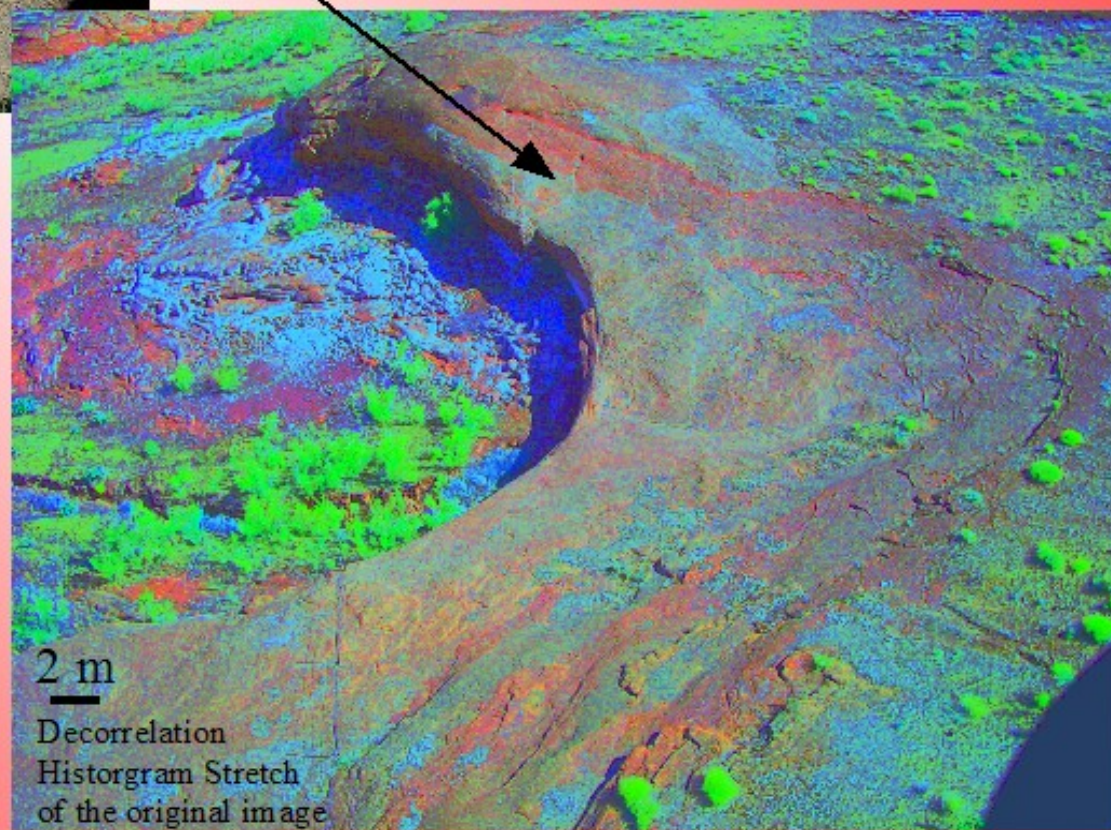


Airphoto mosaic of region surrounding a bed rock knob & stream-cut cliff face in the Navajo Sandstone, Lake Powell, Utah. The images illustrate the versatility of the radio-controlled aircraft imaging system. All pictures obtained by operator standing in parking lot. (red circle in above image).





Oblique aerial photograph taken from RAVENS aircraft (upper right) of Navajo Sandstone near Lake Powell, southern Utah. Note how subtle color variations in sandstone (image above) caused by spatial changes in cement and grain mineralogy are enhanced for mapping by image processing (lower right). 2m scale bar in lower left foreground – scale varies because of perspective (oblique view).



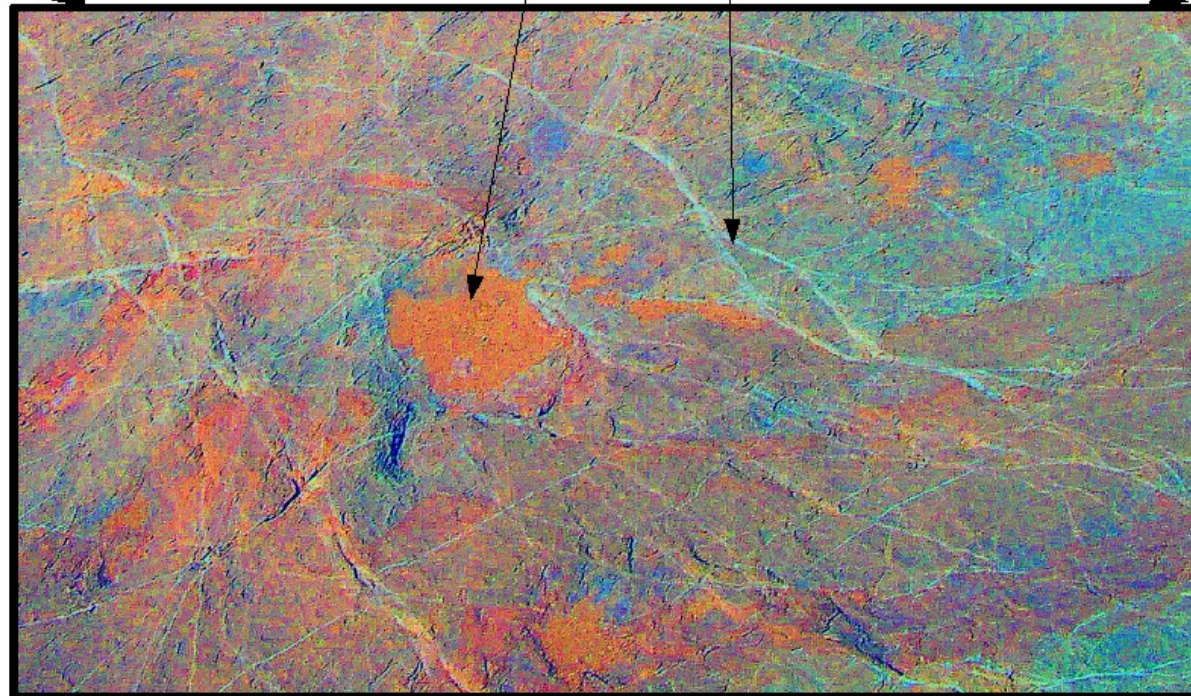
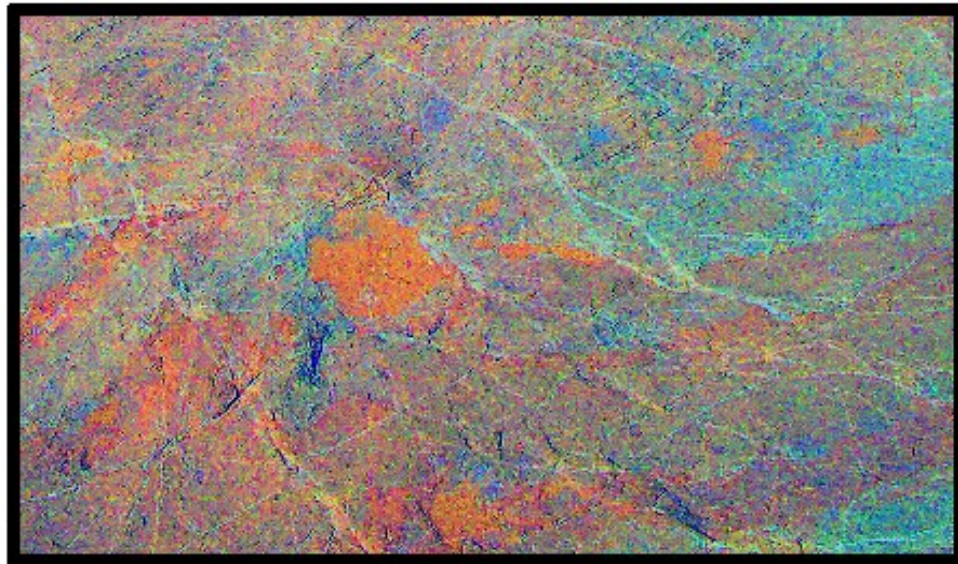
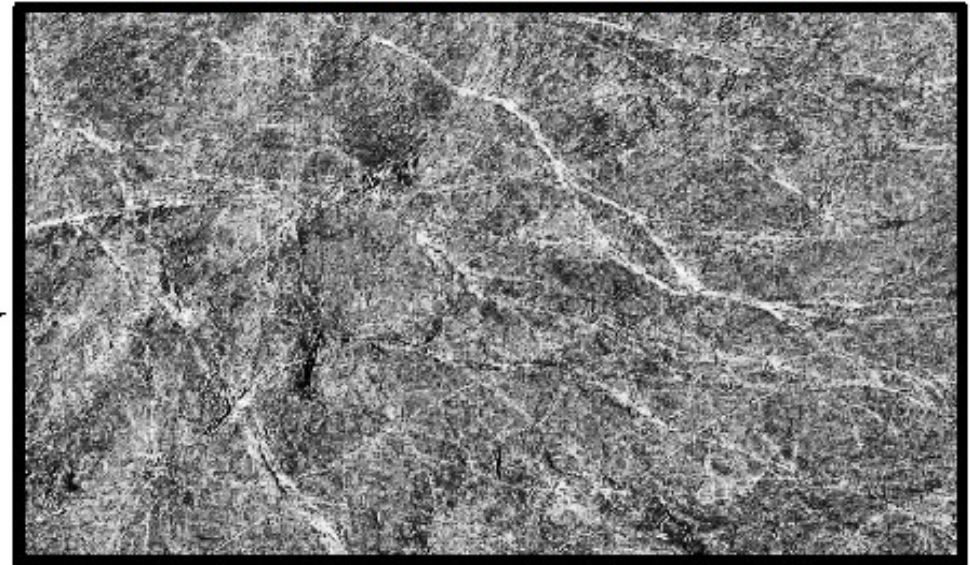


Figure: Oblique-angle aerial photograph of surface of Navajo Sandstone near Lake Powell, Utah. (0524965 E. 4151774 N. Zone 12 S, UTM). Note variable coloration on rock surface caused by variations in mineral content and thin white deformation bands (small faults). Bottom image – decorrelation stretch of region in black rectangle to enhance color variation caused by mineral variability and structural features.

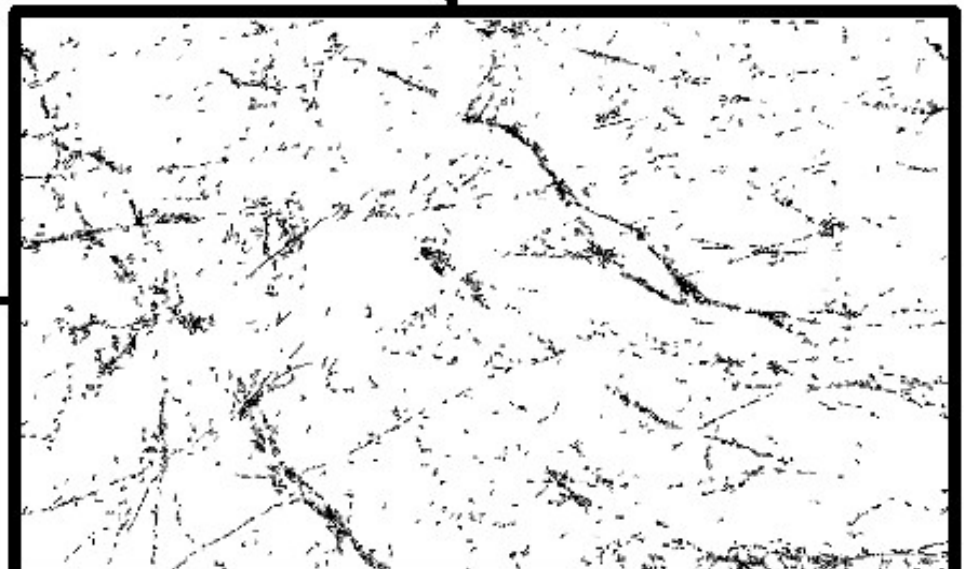
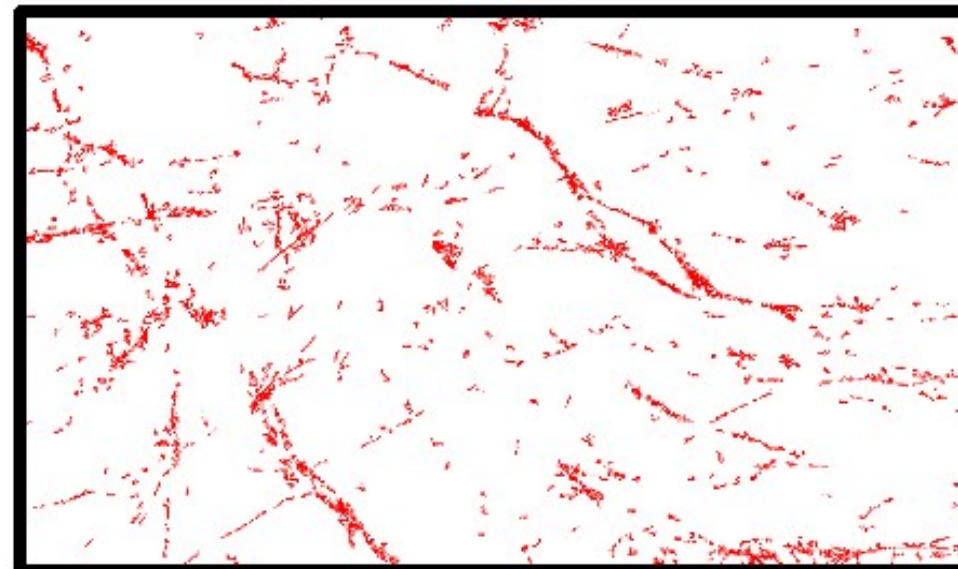
1. Decorrelation Stretch



2. Transformed to Gray Scale



1 m



4. Speckle reduction via morphological opening

3. Gray Scale to Black – White with thresholding

Figure: Image processing to extract deformation band (small fault) pattern from original aerial photograph. Step 1 – enhance color contrast by decorrelation stretch of original image. Step 2 – transform color image to gray scale followed by Gaussian smoothing and adaptive histogram equalization. Step 3 – Create black and white image from gray scale using pixel intensity thresholding. Step 4: Reduce unwanted speckling by morphological opening operation. Remaining pattern is dominated by traces (red) of deformation bands that cut the rock matrix.