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Mesaverde Project: Preliminary Field Analysis

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Focus

Our focus in the field has been to find potential sites for fracture analysis and take preliminary notes and measurements on fracture patterns and orientations at these sites.

Locating potential sites:
Locations were selected based on density of fractures, presence of pavements, access (public lands), ability to view fracture patterns above and below section of interest (do the fractures end, or continue into overlying ss/shale), and size of outcrop.

Terminology

- Locations: areas where sites are concentrated.
  - ex: Green River, Asphalt Ridge
- Sites: individual outcrops with potential for fracture study.
  - 2 types of sites based on data collection.
  - sites where data were **not** collected are labeled with numbers.
    - ex: Jensen Site 1
  - sites where data were collected are labeled with letters.
    - ex: Jensen Site A

Methods (Scan Lines)

For every fracture along a horizontal transect the following were recorded:

-distance (m).
-orientation (S&D for vertical sections, T&P for pavements).
-trace length (cm).
-gross surface (straight, wavy, or curvy).
-micro-surface (rough, smooth).
-coating (Fe_2O_3, calcite).
-vein, open, or closed (aperture included for open fractures).
-upper and lower termination (whether the fracture ended within the unit, traversed the entire unit, ended in another fracture, or continued into the underlying and overlying units).
-evidence of slip (yes or no, if yes type).

For every vertical outcrop the layer thicknesses were also measured.

Scan Line Example: Chart of Measurements Taken in the Field

Orientation of tape	Distance (m)	bd,flt,frct	strike	dip	trace length (cm)	gross surface
122	22.48	fracture	219	71	250	wavy
122	23.51	fracture	235	81	150	straight
122	24.2-26.6	--covered/eroded--				
122	28.42	fracture	219	83	20	straight
122	28.46	fracture	225	84	35	wavy
122	29.67	fracture	224	81	200	straight
122	30.35	fracture	003	87	200	straight
122	30.42	fracture	240	84	115	wavy
122	30.8	fracture	243	85	250	curvy
122	31	fracture	234	81	245	wavy
	31	--End of tape--				

micro surface	coating/vein	termination upper	termination lower	open/closed	evidence of slip	Other
rough		through unit	through unit	closed		
rough	calcite coating	through unit	in unit	closed		
--covered/eroded--						
rough		fracture unit	in unit	closed		
rough		in unit	in unit	closed		
smooth		in unit	through unit	2 cm		
rough		in unit	through unit	0.75 cm		
smooth	calcite coating	in unit	in unit	closed		@ 30m-fracture swarm-
rough		through unit	through unit	closed		continues into upper ss
rough		through unit	in unit	closed		
--End of tape--						

Methods (Fracture Mapping)

Outcrop photographs taken from an airplane were used to map fracture patterns, fractures were selected at random and the following data were recorded:

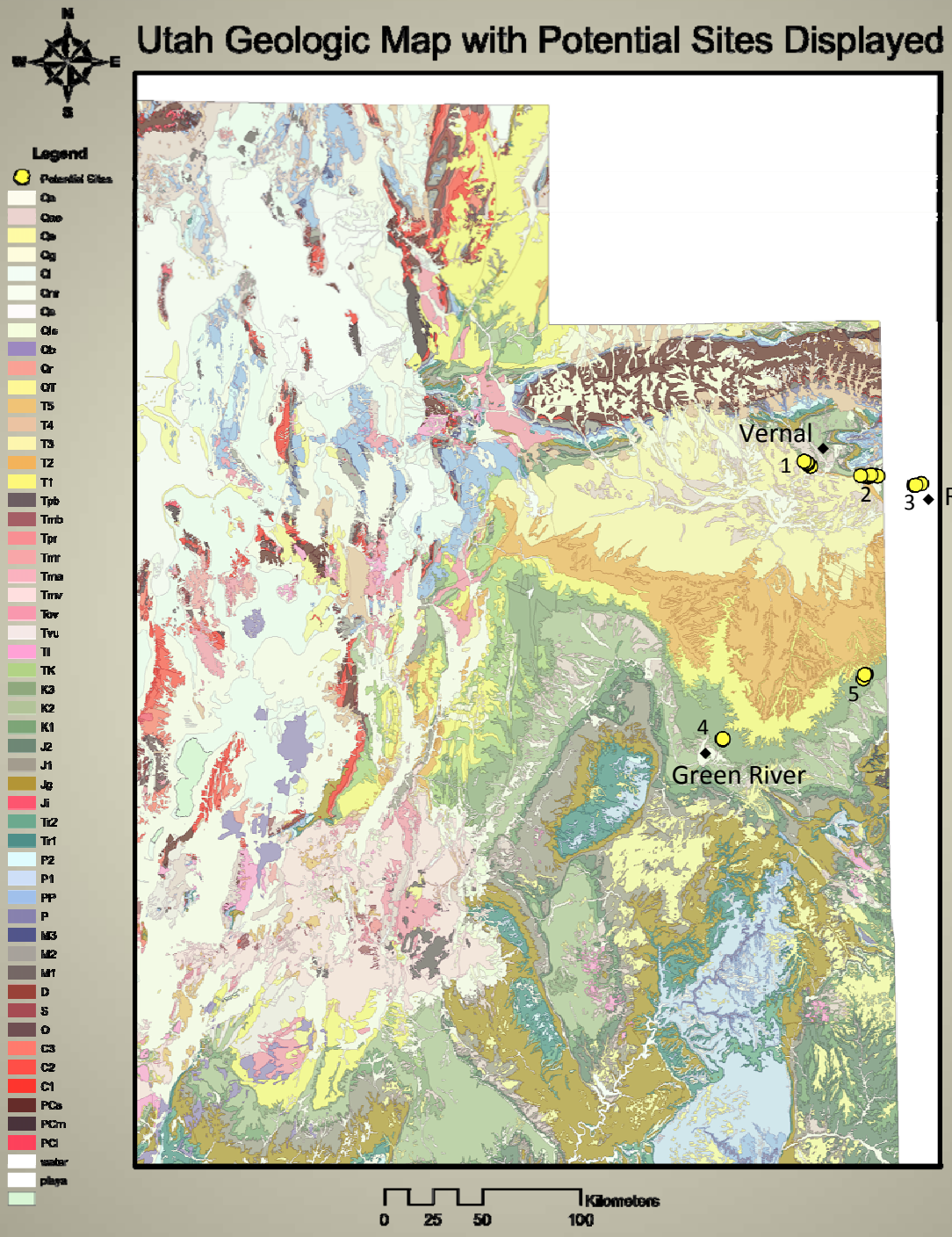
-orientation.
-approximate trace length (m).
-micro-surface (rough, smooth).
-coating (Fe_2O_3, calcite).
-vein, open, or closed.
-upper and lower termination (whether the fracture ended within the unit, traversed the entire unit, ended in another fracture, or continued into the underlying and overlying units).
-termination styles (when a fracture terminated into another fracture, the orientation of both fractures were noted as well as the termination style).
-evidence of slip.

Fracture Mapping Example: Chart of Measurements Taken in the Field

*Fracture #	strike	dip	approx. length (m)	micro surface	open / closed / vein	termination upper / left	termination lower / right
1	257	79	9	smooth	closed	covered	through unit
2	026	30	7	smooth	closed	vert, right	horiz.
3	255	83	3	smooth	closed	horiz, right	through unit
4	088	80	5	smooth	open	through unit	in unit
5	305	65	12	smooth	closed	in unit	right angle
6	045	55	2	rough	closed	horiz.	in unit
7	055	79	16	smooth	closed	through unit	horiz, right angle
8	315	61	7	smooth	covered	vert, acute	in unit
9	349	39	9	smooth	closed	in unit	in unit
10	336	48	13	rough	closed	in unit	in unit
11	041	78	14	rough	closed	through unit	through unit
12	078	81	7	rough	closed	in unit	horiz, curves into

*fracture number correlates with number on fracture map

Utah Geologic Map with Potential Sites Displayed



Locations

1. Asphalt Ridge
2. Jensen
3. Rangely
4. Tusher
5. San Arroyo

Selected Sites

Datum ***NAD27 CONUS***

Name	Date / Time	UTM coordinates	Altitude
Asphalt 1	02-JUL-09 8:12:09AM	12 T 629327 4466314	5211 ft
Asphalt 3	02-JUL-09 9:23:46AM	12 T 627292 4468144	5372 ft
Asphalt 4	02-JUL-09 10:11:14AM	12 T 626081 4468840	5542 ft
Asphalt A	20-AUG-09 5:41:57PM	12 T 627651 4467691	5378 ft
Jensen 2	01-JUL-09 11:07:34AM	12 T 662194 4461613	5563 ft
Jensen 3	01-JUL-09 11:41:32AM	12 T 663430 4461179	5594 ft
Jensen 5	01-JUL-09 1:43:17PM	12 T 658606 4461450	5314 ft
Jensen 6	01-JUL-09 1:57:42PM	12 T 660111 4461772	5364 ft
Jensen 7	01-JUL-09 2:26:23PM	12 T 654725 4461297	5285 ft
Jensen A	18-AUG-09 7:21:42PM	12 T 661807 4461698	NA
Jensen B	19-AUG-09 11:01:34AM	12 T 659109 4461403	5358 ft
Jensen C	20-AUG-09 11:19:16AM	12 T 652038 4461885	5230 ft
Rangely 3	30-JUN-09 5:09:02PM	12 T 682653 4456641	5842 ft
Rangely A	17-AUG-09 3:54:52PM	12 T 681947 4456369	5748 ft
Rangely B	17-AUG-09 6:45:05PM	12 T 680834 4455716	5814 ft
Rangely C	18-AUG-09 9:10:37AM	12 T 685527 4457390	5993 ft
San Arroyo 1	17-JUL-09 3:23:23PM	12 S 657319 4360591	6277 ft
San Arroyo 2	17-JUL-09 5:11:01PM	12 S 656819 4360313	6175 ft
San Arroyo 3	17-JUL-09 5:20:03PM	12 S 656964 4360312	6223 ft
San Arroyo 4	17-JUL-09 5:28:29PM	12 S 657109 4360376	6262 ft
San Arroyo 5	17-JUL-09 5:45:58PM	12 S 656170 4358240	5873 ft
San Arroyo A	18-JUL-09 9:49:32AM	12 S 657138 4360524	6438 ft
San Arroyo B	18-JUL-09 3:58:32PM	12 S 656836 4360396	6277 ft
Tusher A	16-JUL-09 10:21:08AM	12 S 584474 4327830	4665 ft
Tusher B	16-JUL-09 4:46:05PM	12 S 584691 4327271	4700 ft
Tusher C	19-JUL-09 9:19:23AM	12 S 584704 4327821	4637 ft

Scan Lines/Horizontal Transects

- Locations: Tusher and San Arroyo Canyons.

Tusher Canyon (Green River, UT)

- *Location:* Tusher Canyon.
- *Overview:* approx. 10 miles northeast of Green River, the site is located up Tusher Canyon where the road climbs out of the wash and onto the Buck Tongue of the Mancos Shale.
- *Unit:* Kc (Castlegate Sandstone).
- *Work done:* located potential sites and took 3 horizontal transects (two dip slope, one x-section).
- *Type of outcrop:* dip slope and x-section exposure.
- *# of potential sites:* 3 (sites with measurements: 3).

Tusher Canyon, cont.

- Offers excellent exposure of dip slope surface where the overlying Buck Tongue of Mancos Shale has been eroded away.

- X-section/vertical exposure is present in the walls of Tusher Canyon. Canyon walls also allow observation of fracture patterns above and below the section of interest. Plumose structures can be seen on joint surfaces along canyon walls.

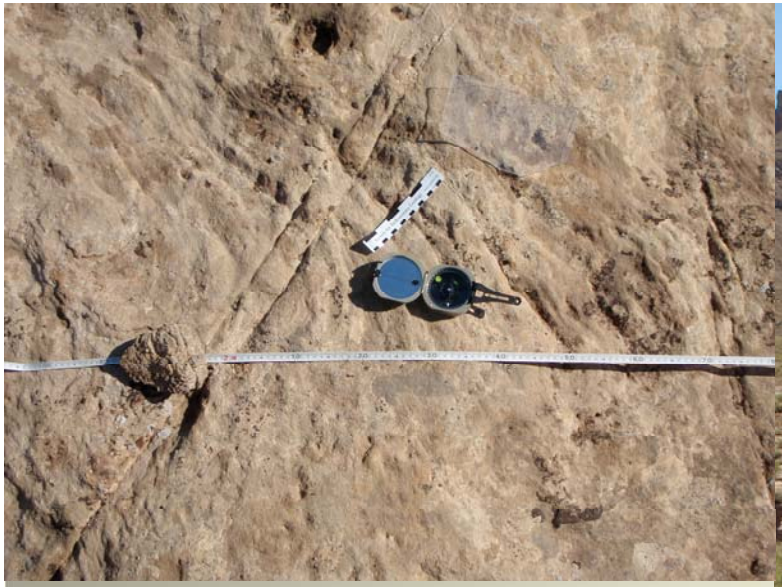
- *Bottom Line*
  - excellent dip slope exposure as well as vertical exposure.
  - potential for more outcrop exposures in the near vicinity (may require extensive hiking).

Tusher Canyon: Directions

- From Green River drive east to Hastings Road (a.k.a. road up the Green River) and turn left/north, drive approx. 6.5 miles, and turn right/east (after a cattle guard) at dirt road marked by an old wooden sign, located ¼ mile after steep dip in road (road damage). Road is labeled on some maps as Tusher Canyon Road (road follows wash most of the way so do not attempt in bad weather). Drive up Tusher Canyon for approx. 7.3 miles, when road makes a sharp right hand turn and leaves the wash you have reached the Castlegate pavements.

Tusher Site A

18 meter horizontal transect taken on dip slope

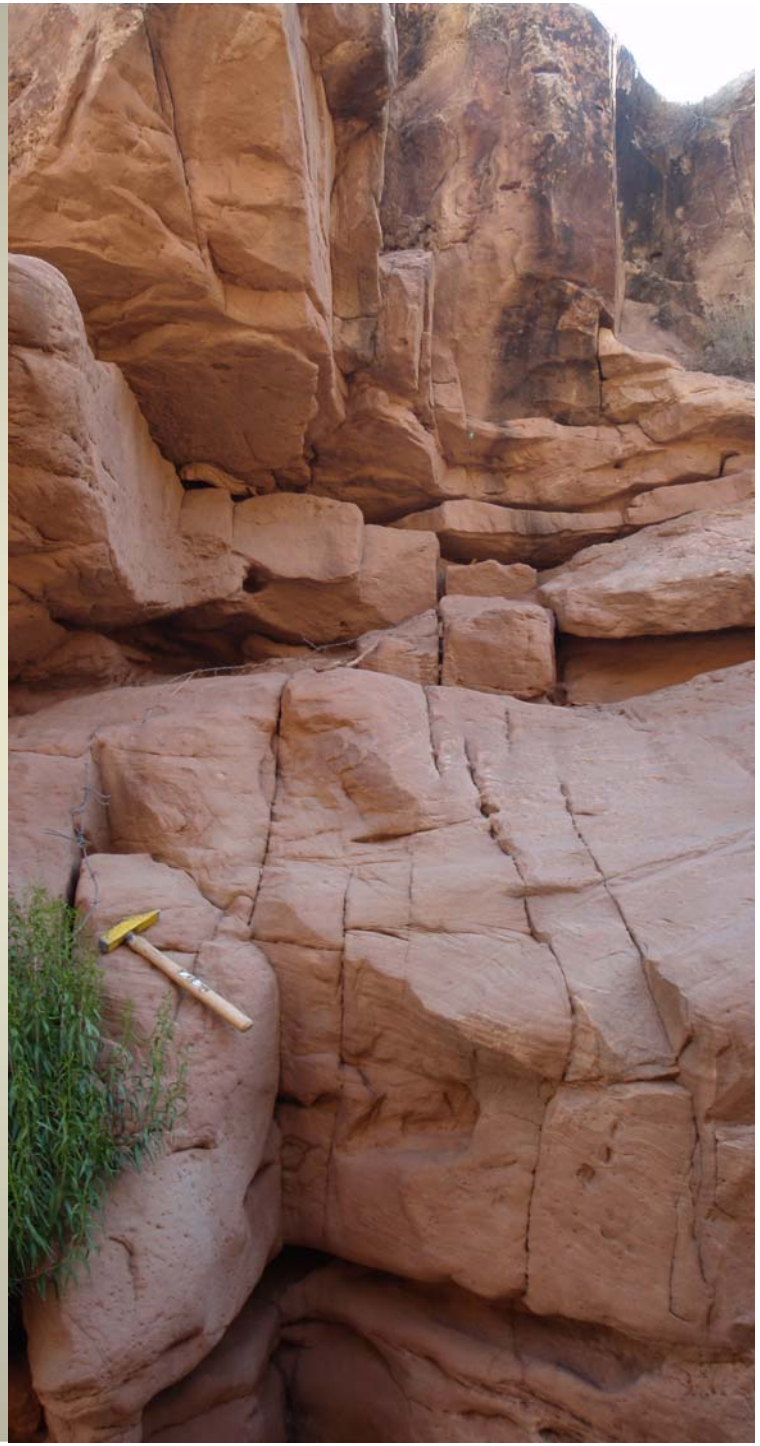


Tusher Site B

27.5 meter horizontal transect taken on dip slope

Tusher Site C

31 meter horizontal transect taken
on vertical exposure



San Arroyo Canyon (UT-CO border)

- *Location:* San Arroyo Canyon.
- *Overview:* approx. 20 miles north of Interstate 70 (5 miles west of the Colorado border), the outcrops lie at the end of a well-maintained dirt road up San Arroyo Canyon (maintained for natural gas production).
- *Unit:* Kf – Kt (Farrer-Tuscher Sandstone).
- *Work done:* located potential sites and took 2 horizontal transects (both x-section).
- *Type of outcrop*: x-section exposure.
- *# of potential sites:* 6 (sites with measurements: 2).

San Arroyo, cont.

- Walls of upper San Arroyo Canyon have package after package of vertical exposure; the rocks are highly fractured and erosion of blocks along these fractures is common, resulting in tilted rocks and inaccurate orientation data.

- Fracture patterns above and below the section of interest can be observed at several locations.

- *Bottom Line:*
  - no dip slope exposure.
  - countless x-sectional outcrops present in the canyon walls.
  - Farrer-Tuscher Sandstones continue up canyon, well beyond the end of the road (where we stopped) and therefore there is potential for several more sites farther up the canyon.

San Arroyo: Directions

- From I-70 take the Westwater Exit, and head north, turn right immediately at the first T. Turn left at the white National Fuel Corp. sign (2.5 miles), turn right at the BLM sign toward Bryson Ridge (8 miles). At 10.8 miles there will be a fork in the road, veer right, continue on the main road (there will be several turnoffs once you hit the canyon). Total mileage to Farrer ss outcrops = 20.2 miles.

San Arroyo Sites

vertical exposures

San Arroyo Sites

eroding blocks

Fracture Mapping

- Locations: Asphalt Ridge, Jensen, and Rangely

Asphalt Ridge (Vernal, UT)

- *Location:* Asphalt Ridge.
- *Overview:* sites lie along a prominent ridge approx. 4 miles southwest of Vernal; the best access to Mesaverde outcrop is 5 miles south of town.
- *Units:* Kmvu and Kmvl (Mesaverde Group upper and lower).
- *Work done:* located potential sites and mapped fractures at one location with the aid of aerial photographs.
- *Type of outcrop:* dip slope and cross section exposure.

Asphalt Ridge, cont.

- Several small canyons provide vertical exposures; one site also offers potential for dip slope measurement.
- There is also potential for more sites on private property (well marked with no trespassing signs).

- *Bottom Line:*
  - area has great access, several potential sites, and potential for measurement on dip slope and vertical exposures (although not at same location).
  - units are not clearly defined (Mesaverde upper and lower) and the dip slope exposures are not as extensive as they are at Rangely.

Asphalt Ridge: Directions

- Turn south on 1500 E., right after Welcome to Naples sign (just east of Vernal). Follow on 1500 E. for approx. 5 miles, outcrops lie along the north side of Asphalt Ridge.

Asphalt Ridge Site 1

x-section exposure

Asphalt Ridge Site 3

Potential for both dip slope and x-section analysis

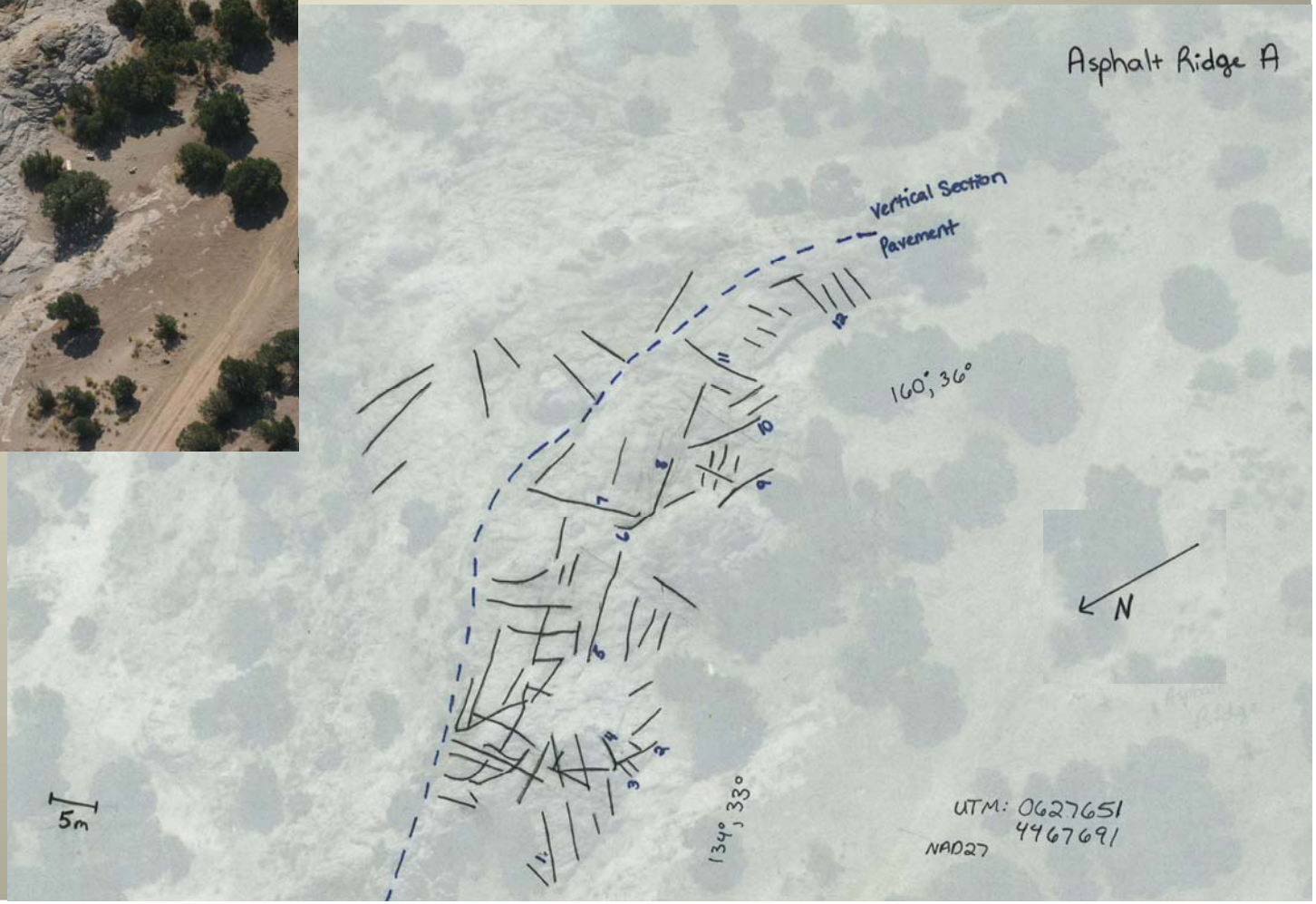
Asphalt Ridge Site 4

Located on private property

Asphalt Ridge Site A

Potential for both dip slope and x-section analysis

Asphalt Ridge Site A



Jensen (East of Vernal, UT)

- *Location:* Jensen.
- *Overview:* Sites lie along a Hogback found both north and south of Highway 40, approx. 10 miles east of Jensen, UT (20 miles east of Vernal).
- *Units:* Kmvu and Kmvl (Mesaverde Group upper and lower).
- *Work done:* located potential sites and mapped fractures at 3 locations with the aid of aerial photographs.
- *Type of outcrop:* dip slope and x- section exposure.

Jensen, cont.

- Dip slope exposures in this area are in a thin, dark brown, coarse grained sandstone; this unit has a very high density of fractures and would allow excellent measurement on dip slope surfaces, the drawback is that at this location the thickness is < 1 meter.
- extensive x-sectional exposures in a finer grained, light colored sandstone.

  (ex: 5 x 200 m)

- *Bottom Line:*
  - area has great access, several potential sites, and potential for measurement on dip slope and vertical exposures (although not at same location).
  - units are not clearly defined (Mesaverde upper and lower) and the dip slope exposures are not as extensive as they are at Rangely.

Jensen: Directions

- Drive east of Jensen (Jensen is 14 miles east of Vernal on Highway 40) approx. 10 miles. The Snake John Reef hogback containing both Mesaverde upper and lower units is located just off of Highway 40 on both the north and south sides of the road.

Jensen Site 2

dip slope exposure

Jensen Site 3 (Kmvl)- dip slopes

thin, dark brown, coarse grained sandstone

view of both units along strike

thicker, finer grained light colored sandstone

Jensen Site 5

x-section exposure, Kmvl

Jensen Site 6

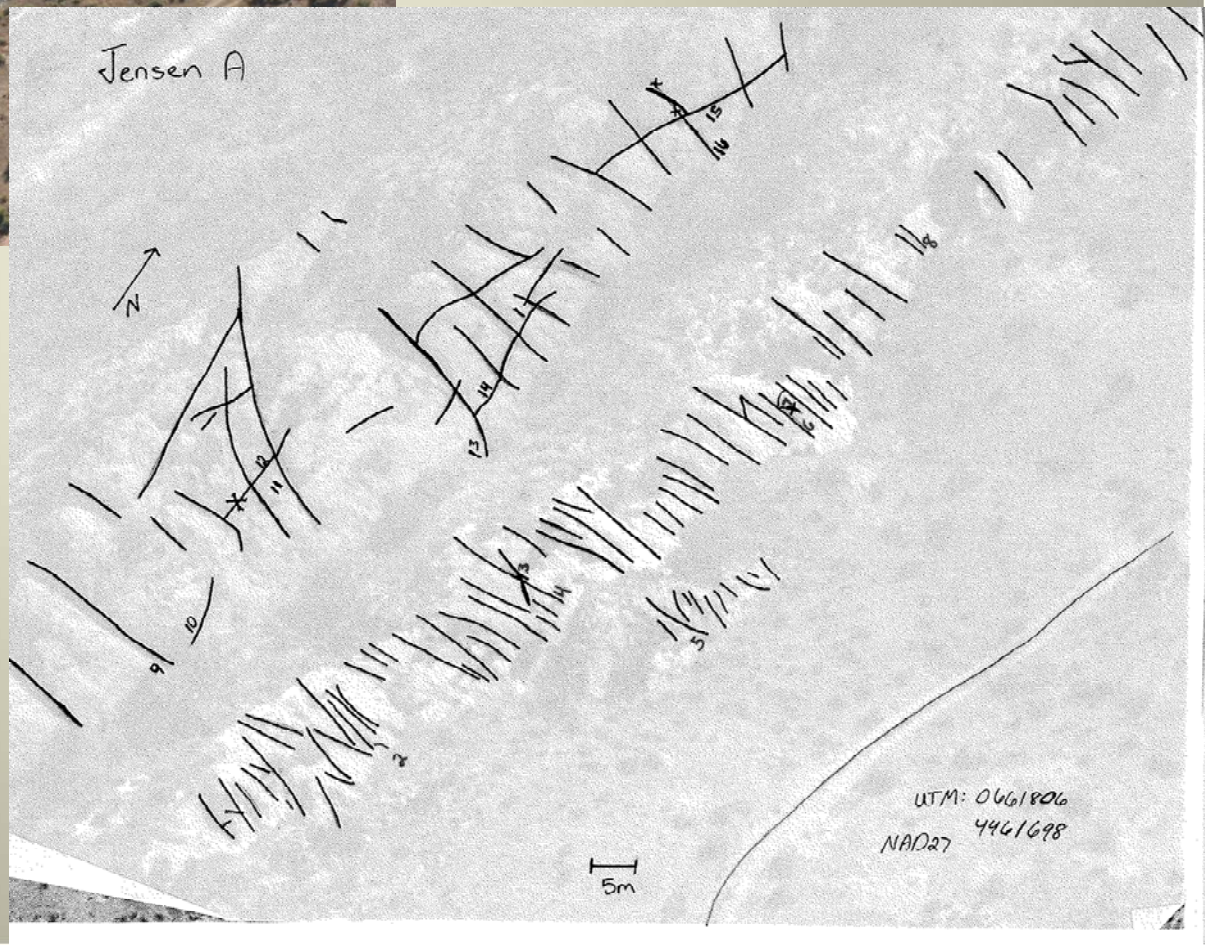
x-section exposure,
Kmvl

Jensen Site 7

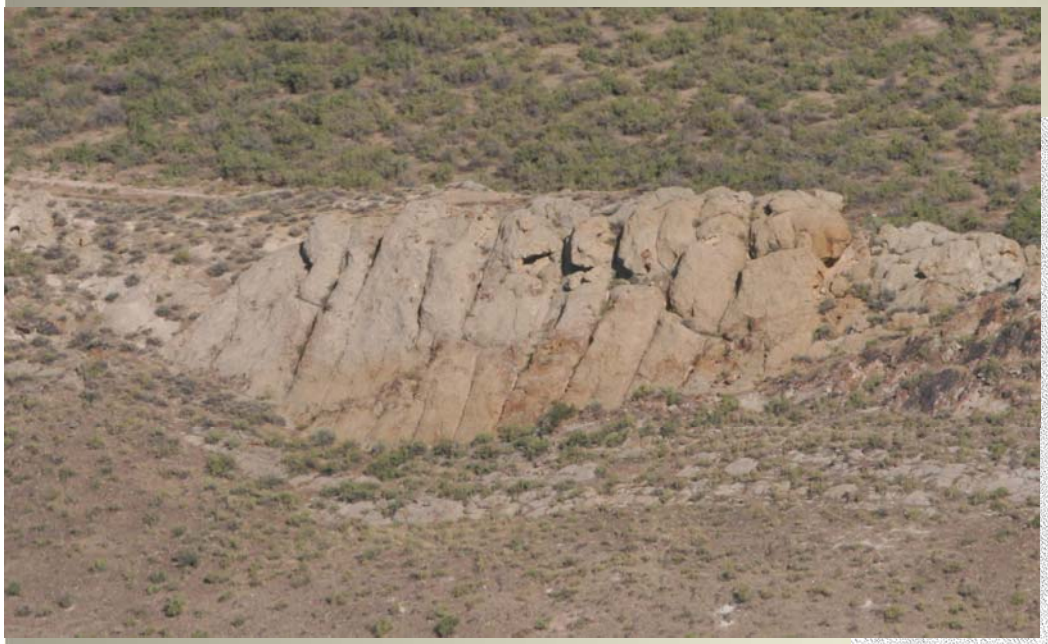
dip slope exposure, Kmvl

Jensen Site A

Fracture Mapping

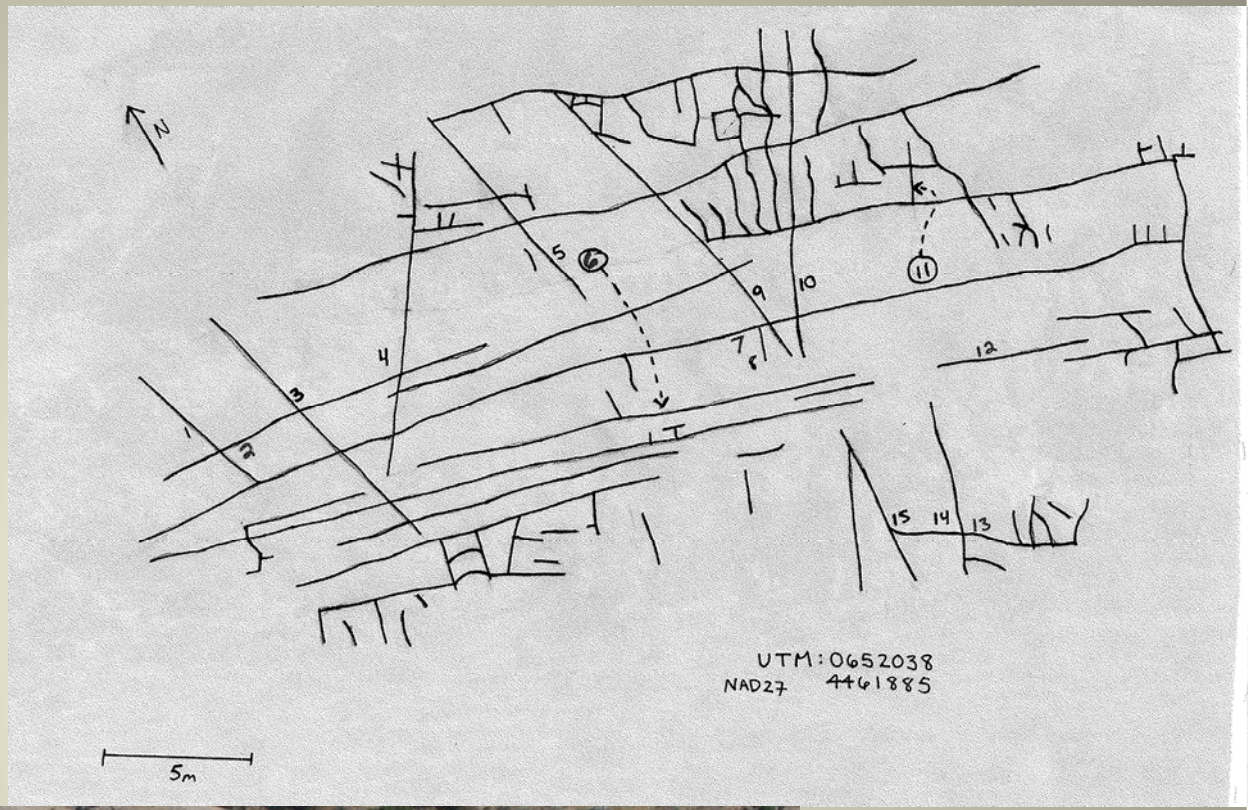


Jensen Site B: Fracture Mapping



Jensen Site C

Fracture Mapping



Rangely, CO

- *Location:* Rangely.
- *Overview:* approx. 8 miles northwest of Rangely, on both the east and west sides of Route 1 (headed toward Blue Mountain).
- *Unit:* Kc (Castlegate Sandstone) and –b- (thin sandstone equivalent to _b_ of Barnume and Garrigues (1979) and partially equivalent to lower unit of Castlegate Sandstone of Cullins (1969)).
- *Work done:* located potential sites and mapped fractures with the aid of aerial photographs.
- *Type of outcrop:* dip slope exposure.
- *# of potential sites:* 3.

Rangely, cont.

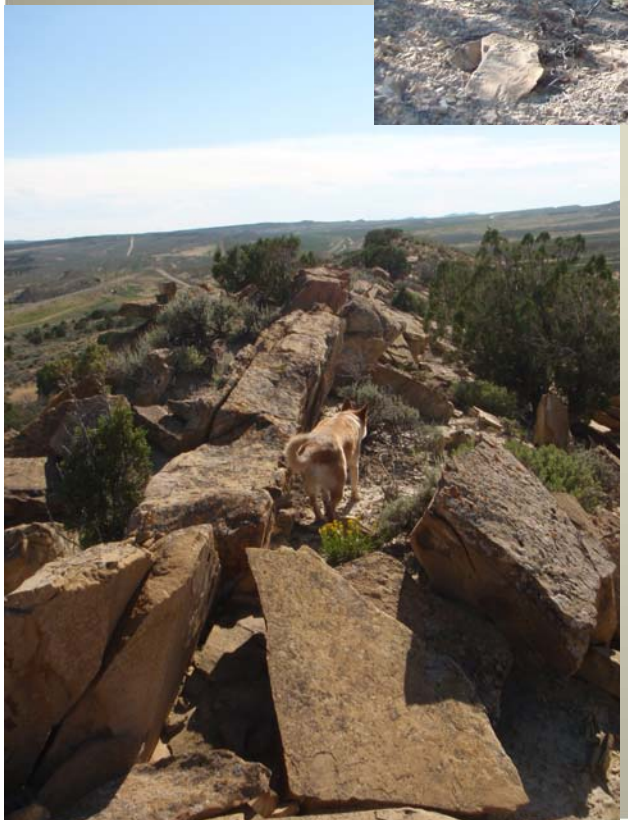
- Both the Castlegate Sandstone and –b- (lower Castlegate?) are heavily fractured and offer extensive exposures of dip slope surfaces.

- The lower unit (-b-) is a thin, dark brown, coarse sandstone similar to that at the Jensen sites. May not be beneficial due to its thickness (1-15 m average, approx. 1 m at the Rangely 2 and 3 sites) and its questionable correlation with the Castlegate Sandstone.

- *Bottom Line:*
  - excellent dip slope exposure (extensive - aprox. 30 m tall x 200 m long, high density of fractures, and good access).
  - units do not provide good vertical exposure.

Rangely: Directions

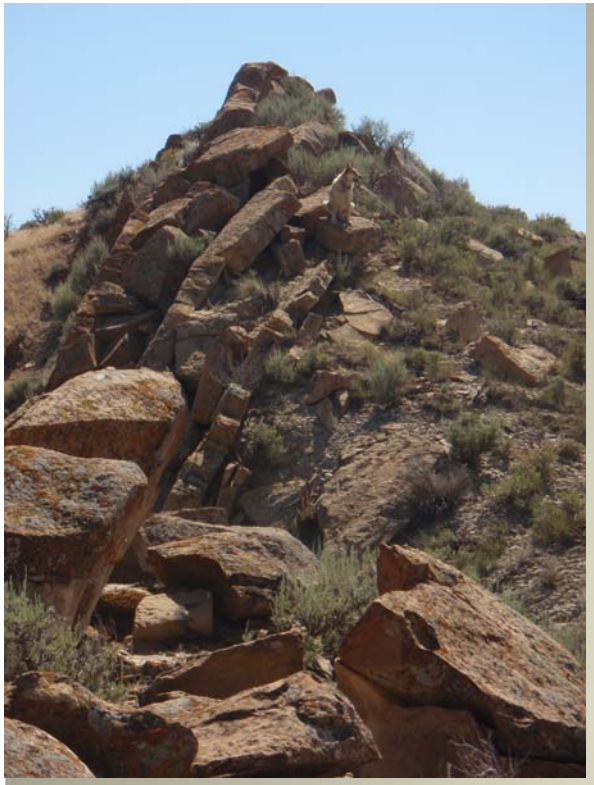
- 3 miles west of Rangely on Highway 64, turn north on Route 1 toward Blue Mountain. Castlegate outcrops are immediately north of train overpass on both the east and west sides of the road.
- Follow the road just north of the railroad to get to sites A and C.
- To get to site B follow the road on the west side of Route 1, south of the railroad.



Rangely Site 3

- -b- (thin, dark brown, coarse grained sandstone)

- excellent exposure for dip slope analysis

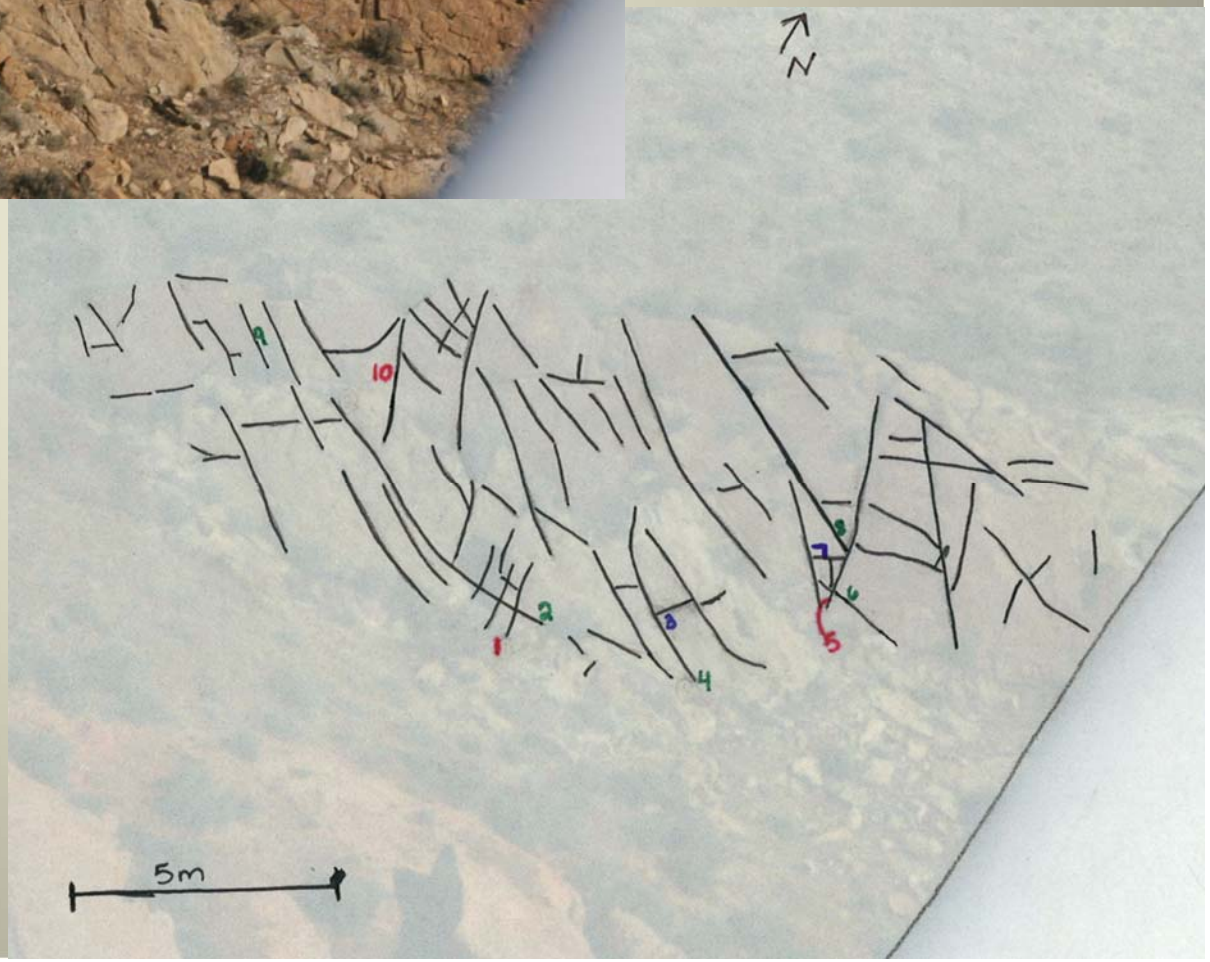


Rangely Site A

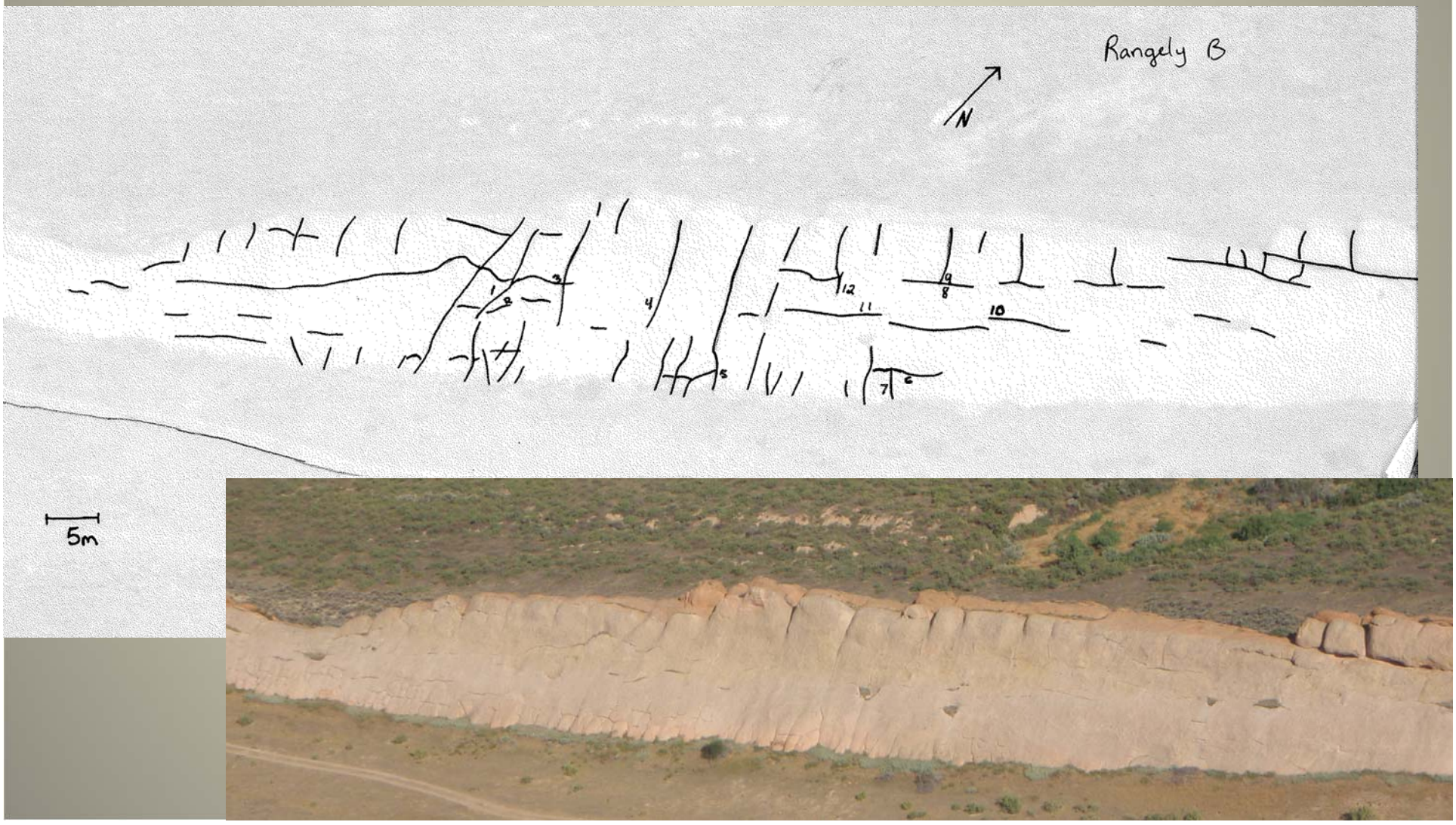
- -b- (thin, dark brown, coarse grained sandstone)
- excellent exposure for dip slope analysis

Rangely Site A

Fracture Mapping



Rangely Site B: Fracture Mapping



Rangely Site C

- Castlegate Sandstone, excellent exposure for dip slope analysis

- 30 x 200 m

Rangely Site C: Fracture Mapping