Hagerman Valley Geology

A Focus on:

The Effect of Large-scale Heterogeneities and Geologic Structures on Spring Spatial Distribution

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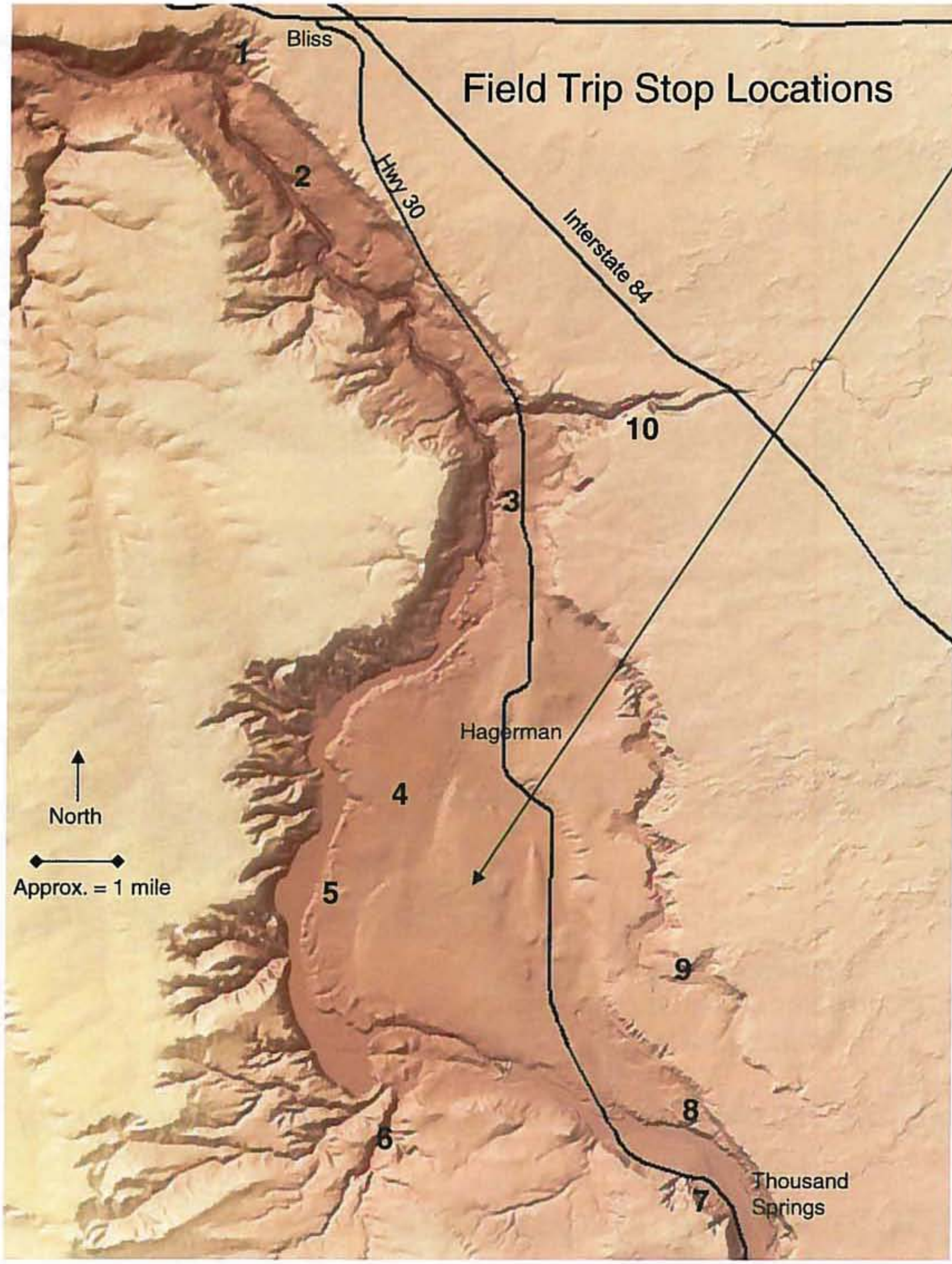
Maley, 2005



General Overview

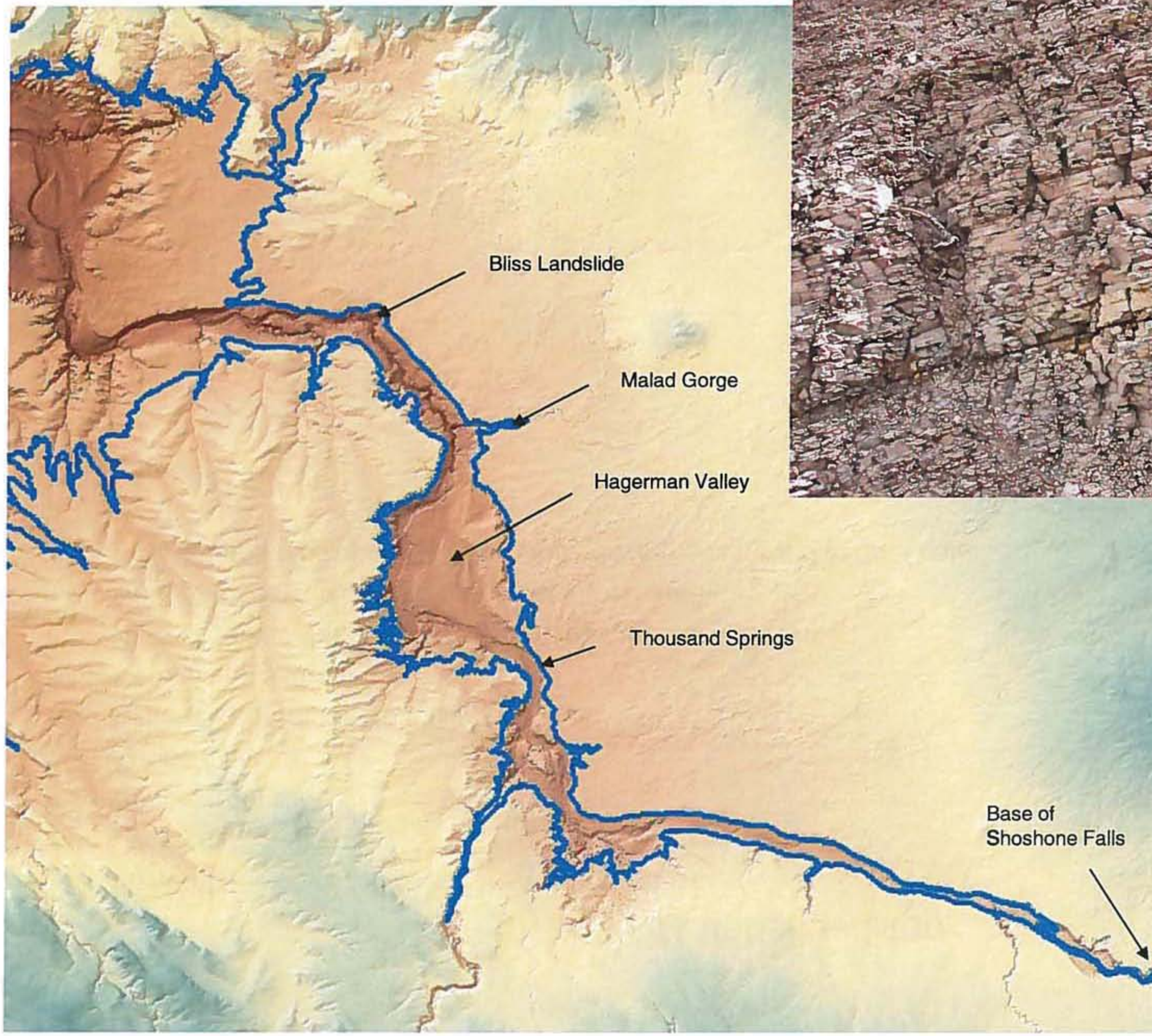
The Hagerman valley is an approximately six square mile expanse of basalt bedrock, Snake River gravels, Yahoo Clay lake sediments, Glenns Ferry Formation (GFF) lake sediments and Bonneville Flood deposits bounded by steep canyon walls on the west and basalt cliffs underlain by lake sediments on the east (Malde, 1972). The valley is bounded by very different geology on the east and west sides of the Snake River. The fine-grained sediments of the GFF dominate the stratigraphy on the west side of the valley, acting as impediments to ground water flow, with intercalated basalt lavas and buried fluvial channel facies acting as hosts for preferential ground water flow within the low-permeability sediments of the Glenn's Ferry Formation hosting anthropogenic perched aquifers (John Welhan, IGS).

The east side of the valley exhibits a cap rock of basalt overlying the GFF sediments from Lake Idaho with more basalt under the lake sediments. Geologic structures have folded, faulted, and tilted the formation layers causing or influencing divergent groundwater flow paths to form unconfined, confined and artesian aquifer systems. These systems include: geothermal artesian aquifers, deep cold water artesian aquifers and of course the ESPAquifer. We will visit locations where both Quaternary age basalts (1.8 m.y. or younger) and Tertiary age basalts (older than 1.8 m.y.) host aquifers that exhibit high permeability and aquifer discharge rates.

Bliss Landslide Stop

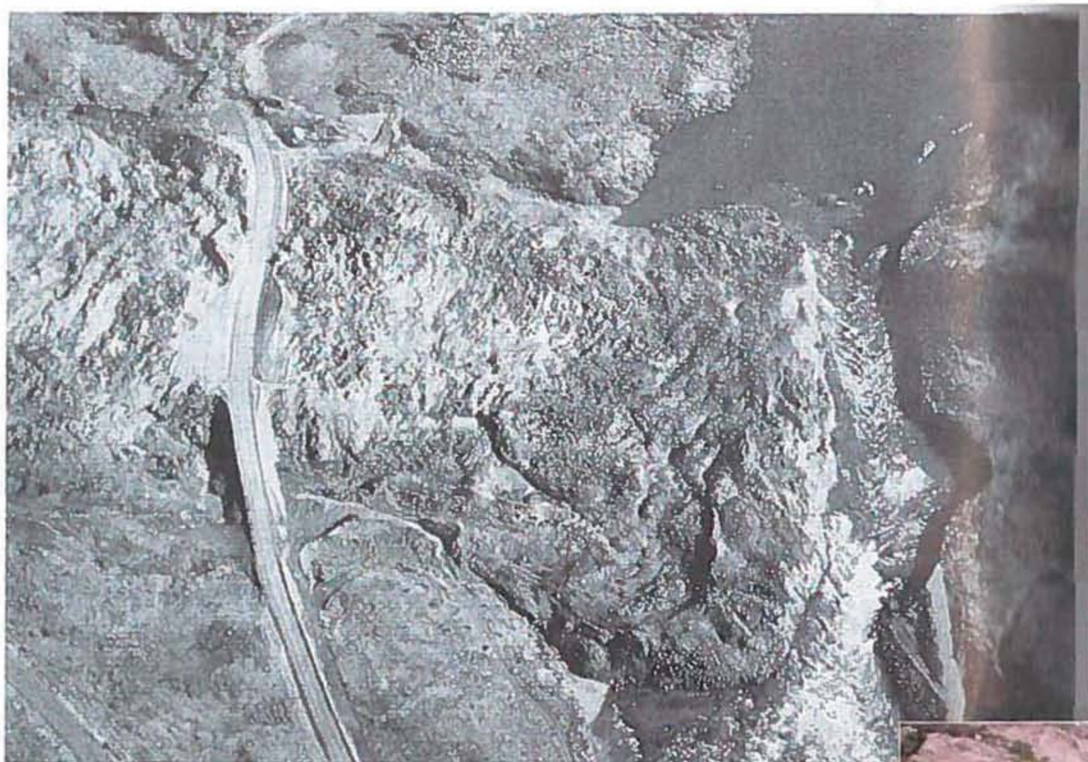
- General geology from one side of river to other.
- Slide characteristics
- Effects from slide
- Yahoo Clay
- Estimate percentage of clay.
- Note slides across river.
- Bliss slide has the last downstream outcrops of Y.C. Fm.
- Note patches in road and hummocky road surface
- Note rotated blocks of Y.C. Fm. while driving down road in road cuts.

"Lake Yahoo"

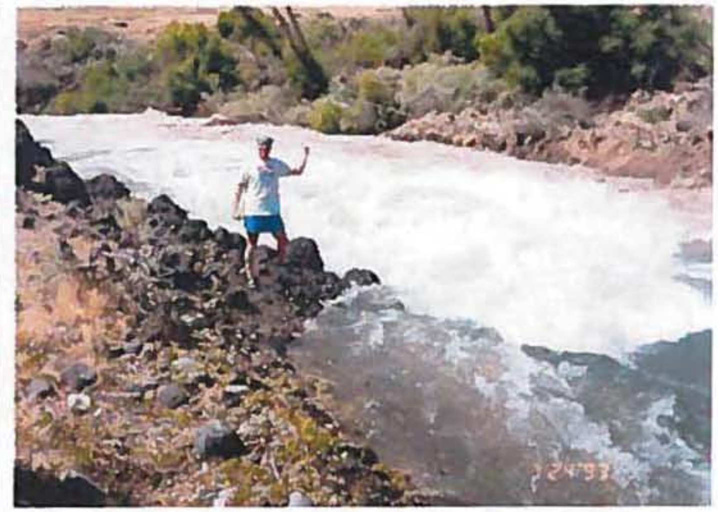


McKinney Butte erupted about 50,000 y.b.p. and discharged a basalt flow into the Snake River Canyon blocking and damming the river which deposited the Yahoo Clay Formation (Malde, 1972) . The lake would have nearly filled the Hagerman Valley from rim-to-rim and extended from Bliss area upstream to possibly the base of Shoshone Falls.

Landslide Events

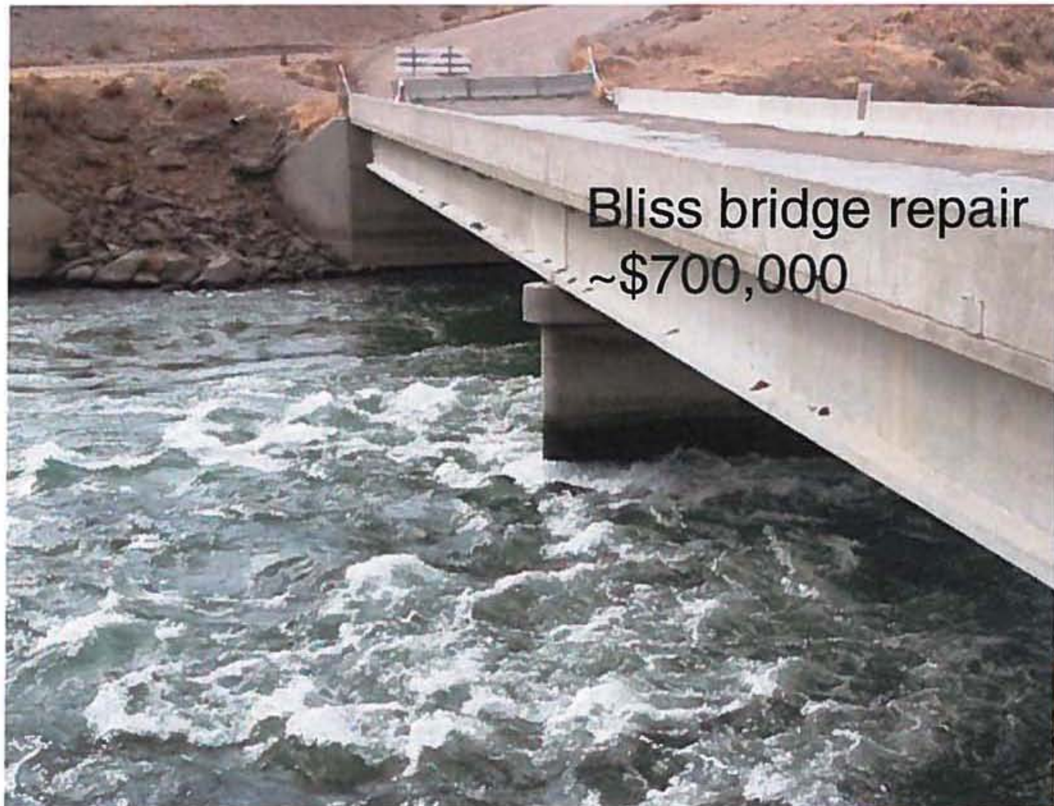


(Maley, 2005)



1993 Bliss Landslide

Impacts from Landslides

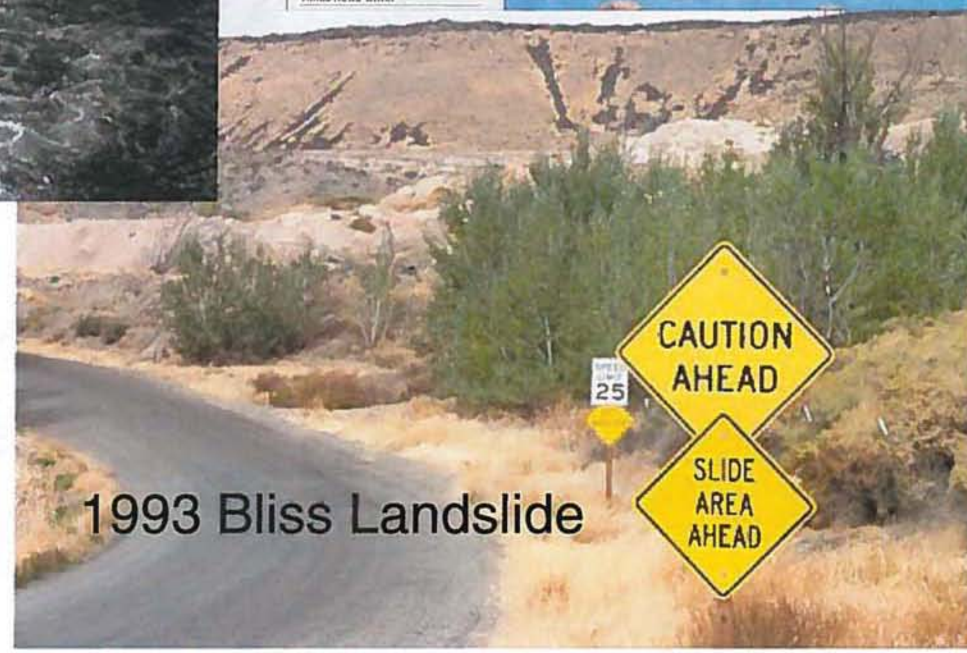



Bridge closure strands some

An Idaho Transportation Department crew barricades off the Bliss bridge early Saturday morning. The bridge was declared unsafe for vehicular traffic after two underwater inspections determined that the high velocity of the Snake River and the unstable foundation of the bridge could result in bridge failure.

Alternate routes will add hours to driving time

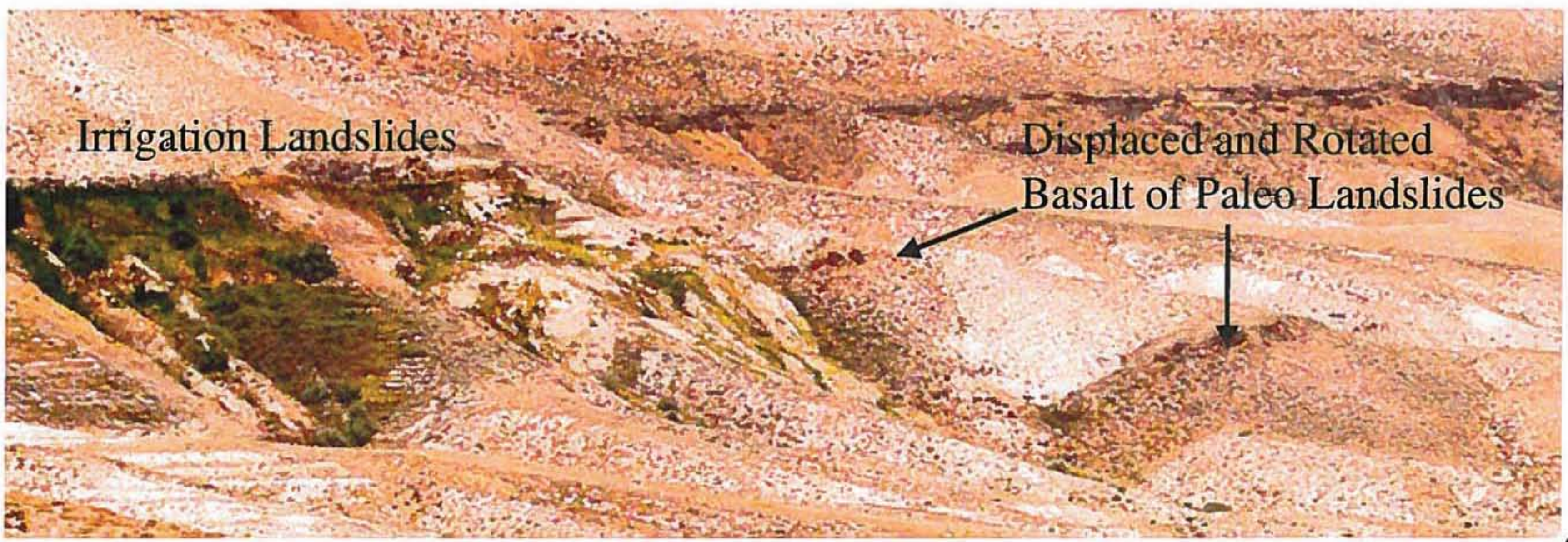
By Julie Penco
Times-News writer



Bonneville Flood Scabland Stop

Recent and Ancient Landslides

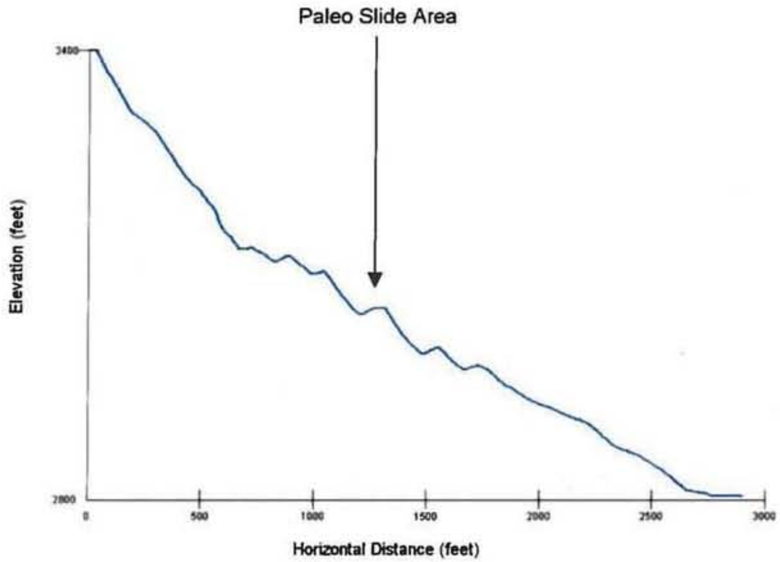
- Stratigraphic relation of YC fm. to landslides.
- Intercalated basalt flow.
- Dry and wet vegetation patterns act as a tracer to both aquifers and stratigraphy.

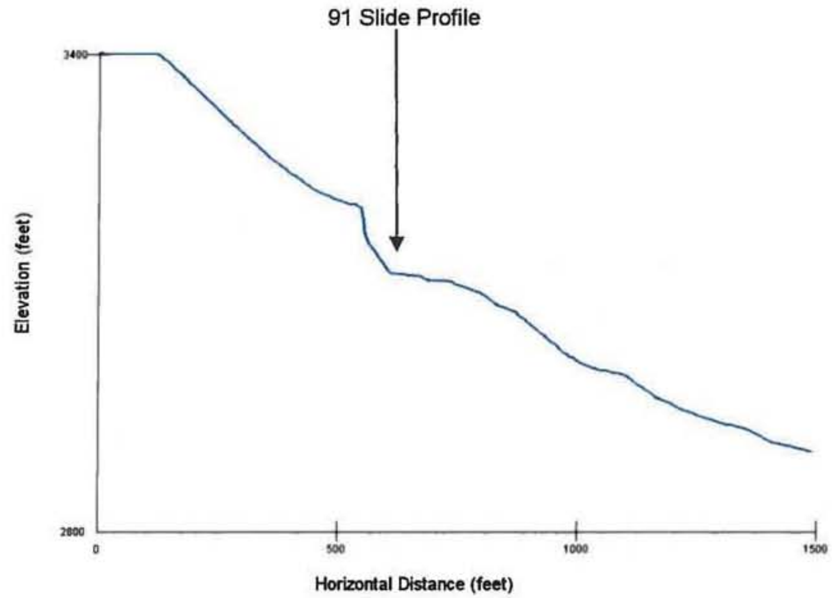


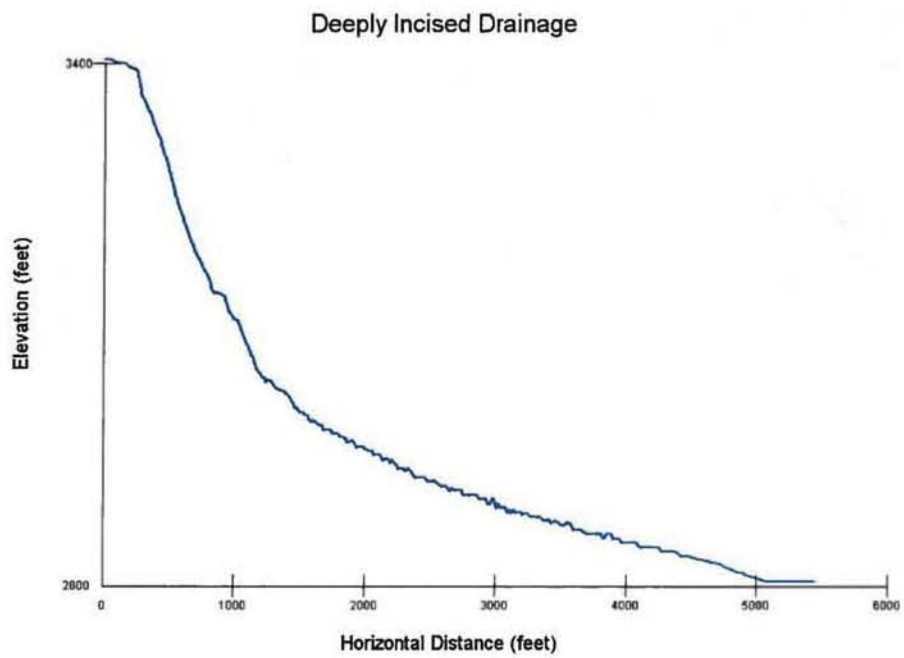
Intercalated Tertiary age basalt within the clay rich sediments of the GFF dated at 3.4 million years old (Hart, 1999).

Discharge from the rubble base of this basalt flow, at only this location of the headwall scarp of the 1991 landslide, averages 200 gpm or 2,900 ac-ft per year. Tracer tests record groundwater flow velocities ranging from 150 to 200 linear feet per day.

Geomorphic Profiles from Hagerman Fossil Beds N.M.







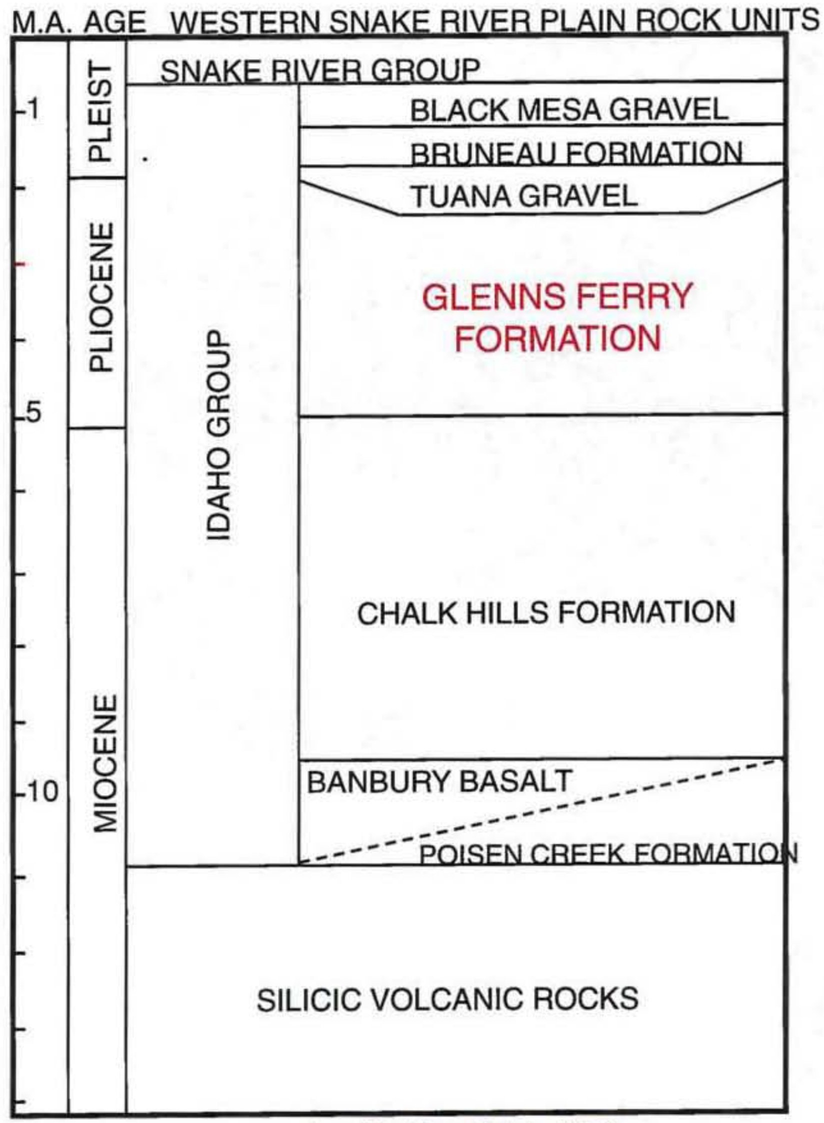
Scoured Scabland Basalt from the Bonneville Flood c.a. 15,000 y.b.p.

•Note scoured flute surface features on basalt and how they trace the paleo flow patterns.

Landslides of Hagerman Valley

'Lake Idaho'

- 5 to 1.5 m.a.
- deposited Glenns Ferry Formation.
- about 50 miles wide and 150 miles long.
- some fossils are radioactive including the official Idaho State Fossil – "The Hagerman Horse".



(modified from Malde, 1972)

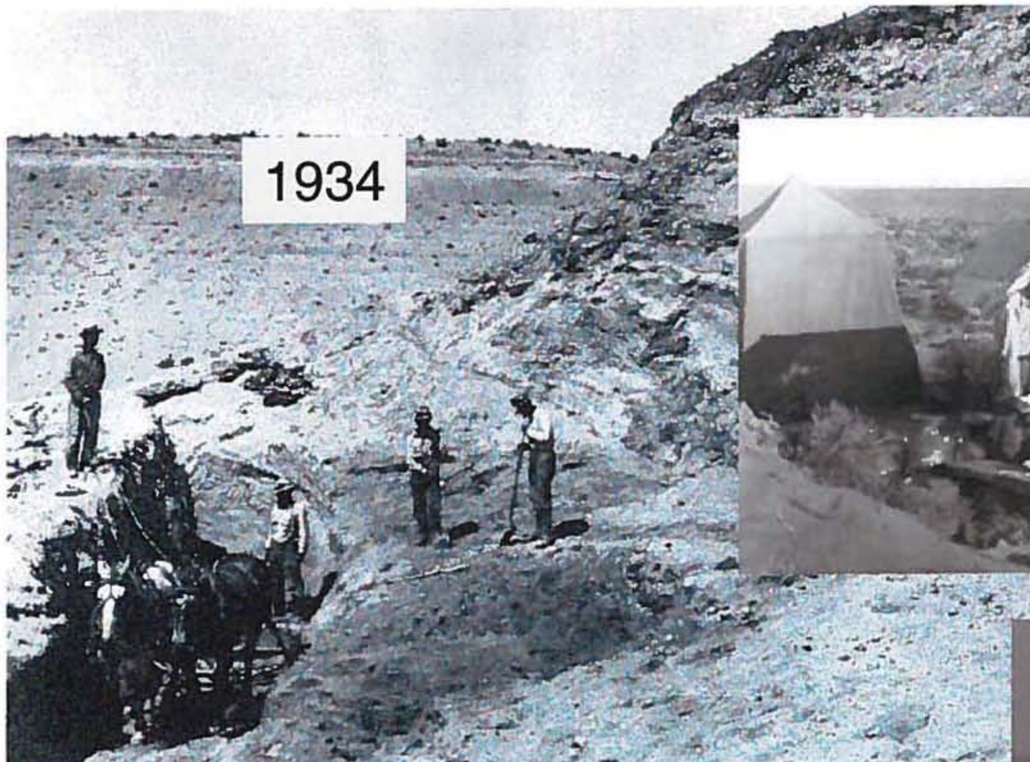
'Hagerman Horse Quarry'

Horse hoof

Water Lilly pollen

Fir pollen

Borophagus (hyena dog)



Horse molars

Turtle shell

Beaver vertebrae

Salmonid vertebrae

Radioactive Isotopes Identified by XRF and SEM/EDS Reconnaissance Analysis (noted with isotope numbers)

sources: (UofI, 2005) and (WSU Transuranium & Uranium Registries, 1997) and (Data Chem, 1997)

- Uranium - 238 & 235
- Thorium - 234
- Radium - 226 & 223
- Lead - 210 & 214
- Bismuth - 214
- Cesium - 137
- Protactinium - 231
- Yttrium
- Barium
- Lanthanum
- Iodide
- Nearly all Lanthanide/Rare Earth Elements.

- ⌧ Aluminum
- ⌧ Chloride
- ⌧ Manganese
- ⌧ Iron
- ⌧ Titanium
- ⌧ Sulfur

- SEM/EDS analysis indicates that U and Th concentrations in carbonate-fluorapatite range up to 5000 ppm.

Radon

(NPS photo)

Cabinet

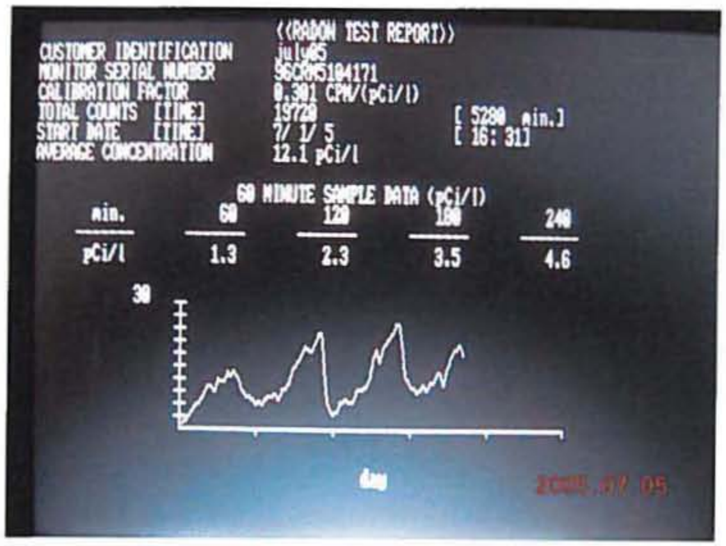
1996 Test

Ave. =

436 pCi/L

Max =

544 pCi/L



Room

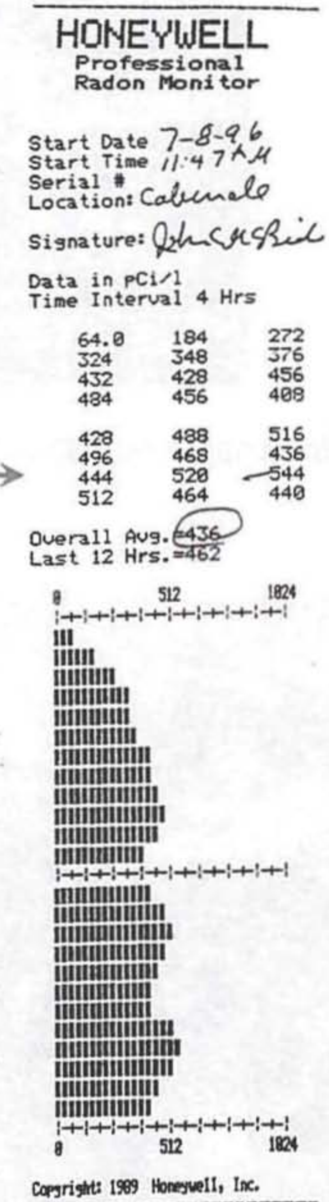
2005 Test

Ave. =

12 pCi/L

Max =

26 pCi/L



HONEYWELL
Professional
Radon Monitor

Start Date 7-8-96
Start Time 11:47 AM
Serial #
Location: Cabinets
Signature: [signature]

Data in pCi/l
Time Interval 4 Hrs

64.0	184	272
324	348	376
432	428	456
484	456	408
428	488	516
496	468	436
444	520	544
512	464	440

Overall Avg.=436
Last 12 Hrs.=462

0 512 1024

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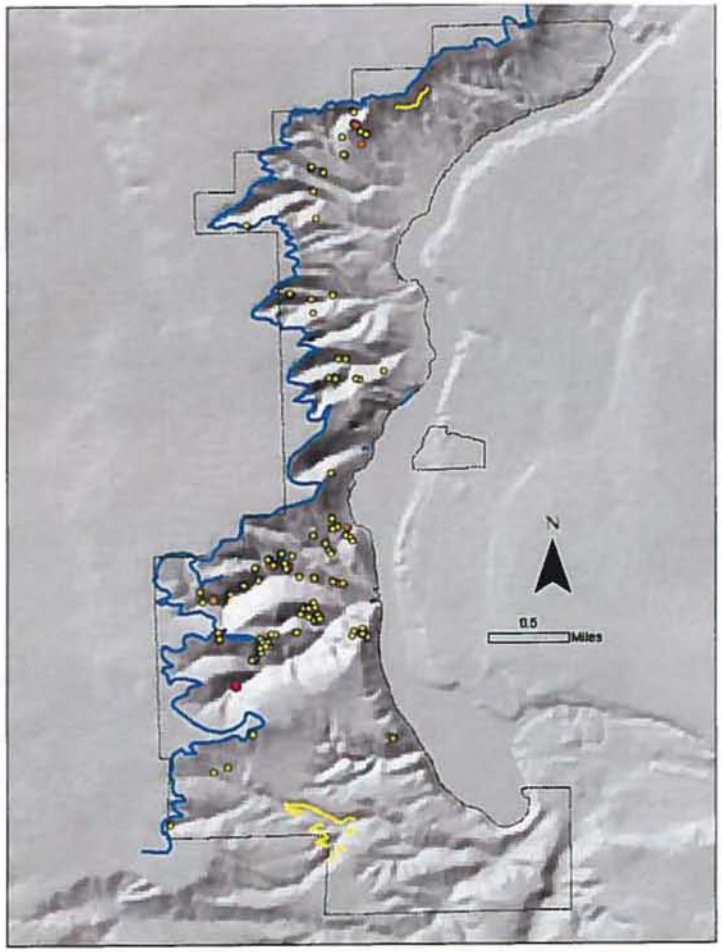
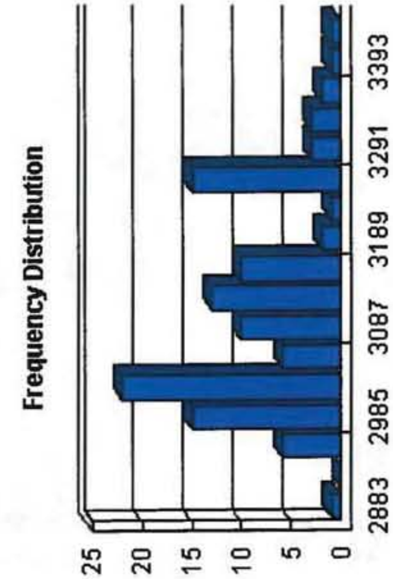
Radioactive Fossil Distribution

and

Summary





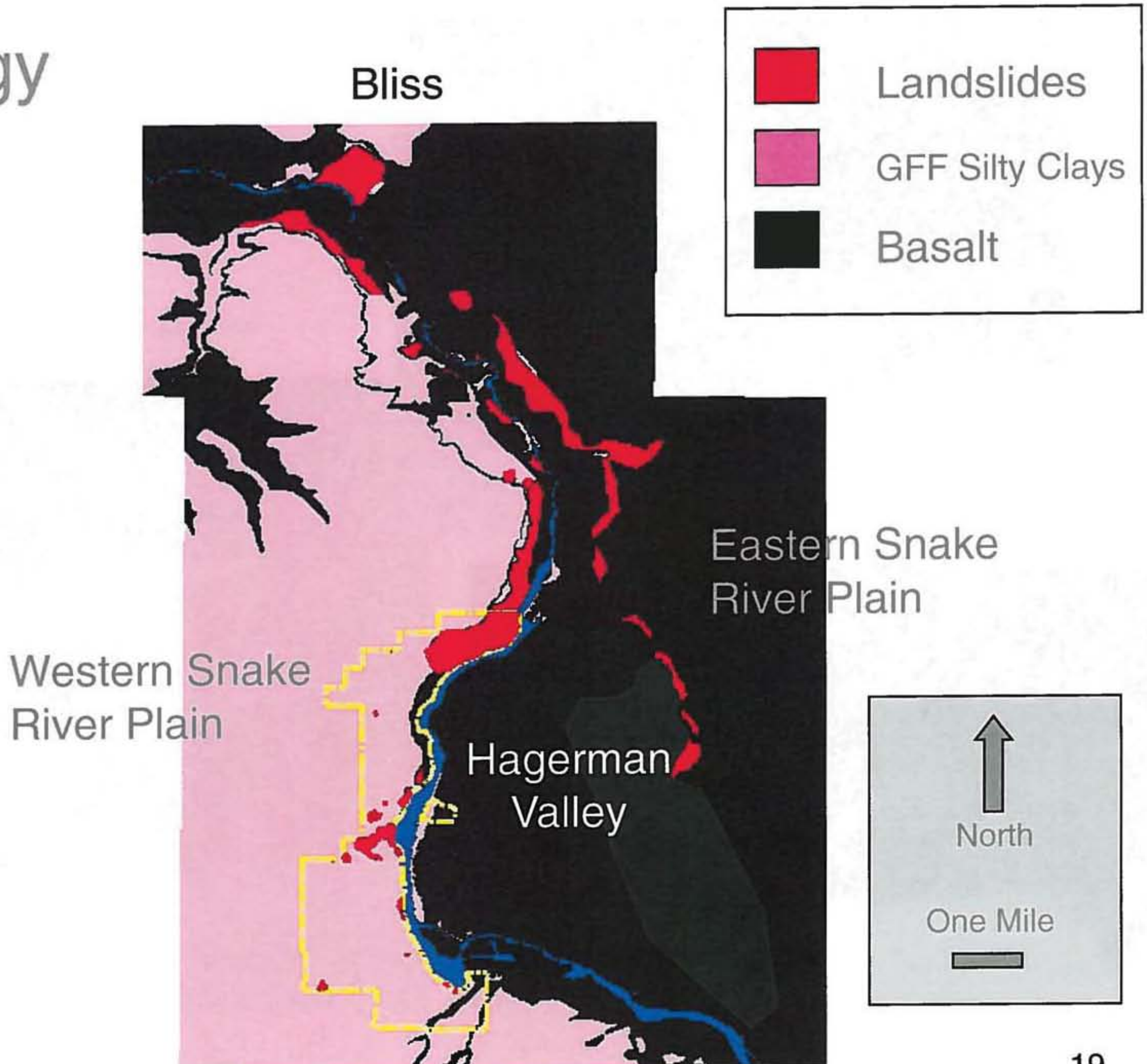
- 75% exhibit radioactivity.
- ~ 50% are 1,500 CPM or higher with one specimen at 21,000 CPM.
- The Idaho State Fossil is one of the ‘hottest’ sites.
- Radon is a health hazard associated with fossil collections.
- Higher radioactivity is associated with permeable rock units (sand) and lower activity from clay rich deposits.
- 130 radioactive fossil sites are documented so far.
- Radioactivity has been documented since 1996 at HAFO.

Land Use Change

1930's

1997 (same location as photo above)

Landslides and Geology



(modified from Malde, 1972)

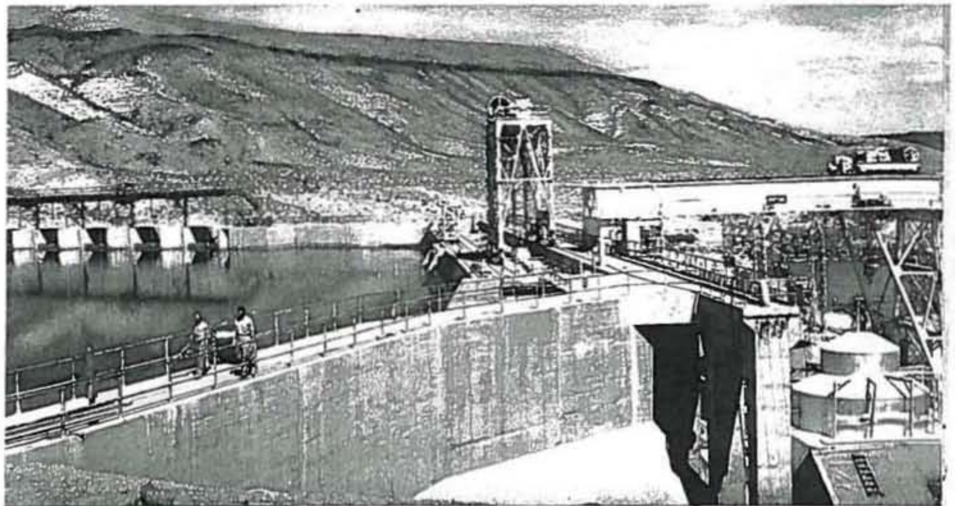
Paleo Block Failures

Malad Gorge block failures with IPCo. Facilities.

Paleo Slide, Rock Fall, and Highways

Roads, bridges and homes built on slides.

Reservoir Associated Landslides



ABOVE, view of combined dam and powerhouse structures looking across right abutment wing wall, spillway section in left distance across reservoir, headwall and powerhouse, with their gantry cranes, at right.

Lower Salmon Done

New power now flows from the fourth and largest dam and powerhouse completed by M-K under Idaho Power Company's huge expansion program, with four generators turning out 87,100 horsepower for homes and business.

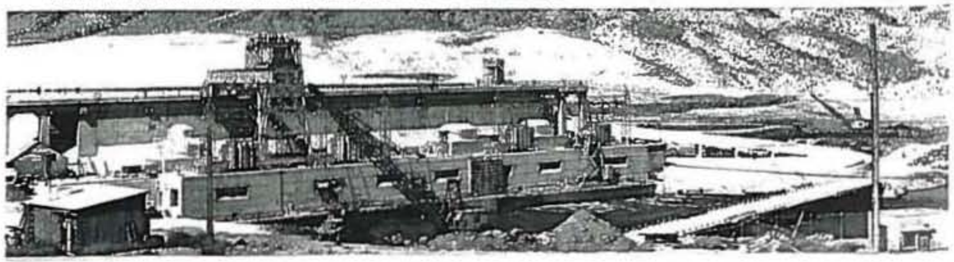
On September 8 the last of four generators started spinning out its 16,250 kilowatts in the beautiful new Lower Salmon Powerhouse whose headwall is a part of Lower Salmon Dam, the structures and installations all built by M-K for the Idaho Power Company to produce 87,100 horsepower (65,000 kilowatts) of electric current. The dam stretches more than 1,000 feet across the Snake River, a concrete structure having a gravity overflow section and a spillway regulated by eight taintor gates to control the river's flow.

This big hydroelectric development, which includes a switchyard to transmit power over the private lines that serve the communities of southern Idaho, is the largest of four now completed in a program M-K is carrying out under Idaho Power Company's $78,000,000 schedule of improvements. A fifth, Bliss Dam and Powerhouse, is still under construction 20 miles downstream.

Only minor jobs and final clean-up operations remained last month. Like its sister dams on the Snake and the near-by Malad River, Lower Salmon has a concrete fish ladder that runs through the dam affording free passage to the fish. To protect this ladder from the hazard of injury by high water from the spillway, a rubble-masonry deflection wall was still being built. All clean-up was to be finished by October 15. Employment had dropped from about 350 last spring to 145 in early September and was rapidly decreasing.

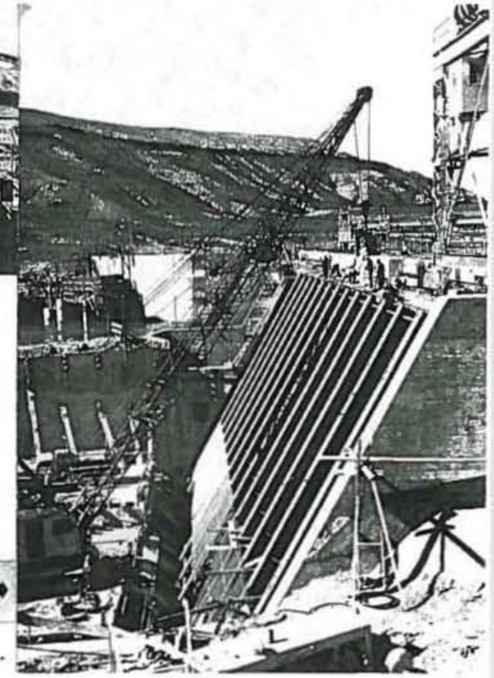
Under Lou E. Steelman as M-K project manager of the entire spread of Idaho Power hydroelectric jobs, the operation has been a smooth and successful one, supervised for Idaho Power by Ed

ABOVE, in powerhouse control room, Glenn C. Johnson, assistant project manager, Robert G. Foster, erection superintendent, Fred McCormick, IPCo resident engineer, and Ed A. Woodhead, IPCo superintendent of power plants. BELOW, panoramic view from right downstream of the new powerhouse, showing curving fish ladder, a graceful concrete structure at right.



Tomorrow's Power Today

Lower Salmon Dam and Powerhouse, nearing completion after beating a tough winter, are turning out 32,500 kilowatts and soon will double this capacity in M-K's latest addition for progressive, privately-owned Idaho Power Company.



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River Corridor Landslides and Effects from Reservoir Management

(source: Hunt, 1984)

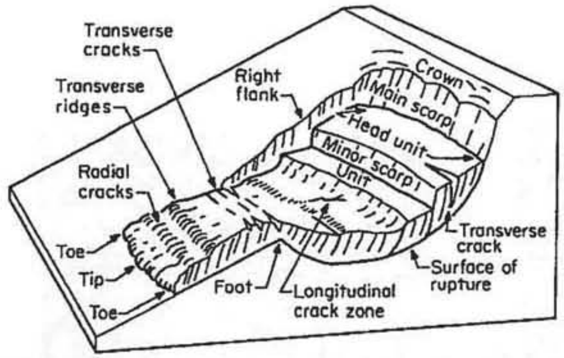


FIG. 9.21 Characteristics and nomenclature of a rotational slide. *[From Varnes (1958).[1] Reprinted with permission of the Transportation Research Board.]*

Birmingham shale of zone 4 is heavily jointed vertically.

Slide History

In the 1930s a large tension crack opened at the top of the slope. Sealing with concrete to prevent infiltration was unsuccessful in stopping movement and the crack continued to open over a period of several years. The rainfall that entered the slope through the vertical fractures normally drained from the slope along pervious horizontal beds. On the day of failure, which followed a week of rainfall, the horizontal passages were blocked with ice. Hamel (1972)[10] concluded that final failure was caused by water pressure in the mass, and the failure surface was largely defined by the existing crack at the top of the slope and the weak basal stratum.

9.2.5 ROTATIONAL SLIDES IN SOILS

General

A common form of sliding in soil formations is the rotation about some axis of one or more blocks bounded by a more or less cylindrical failure surface. The characteristics at total failure and descriptive nomenclature are given on Fig. 9.21.

The major causes are seepage forces and increased slope inclination, and relict structures in residual soils. Usually neither the volume of mass involved nor the distance moved is great; therefore, the consequences are seldom catastrophic although slump slides cause substantial damage to structures. If their warning signs are recognized they can usually be stabilized or corrected.

Recognition

Occurrence

Slump or rotation slides are characteristic of relatively thick deposits of cohesive soils without a major weakness plane to cause a planar failure. The depth of the failure surface varies with geology.

Deep-seated failure surfaces are common in soft to firm clays and glaciolacustrine, and glaciomarine soils. Deep to shallow failure surfaces are common in residual soils, depending on the strength increase with depth and relict rock defects. Relatively shallow failure surfaces are characteristic of colluvial soils.

Surface Features

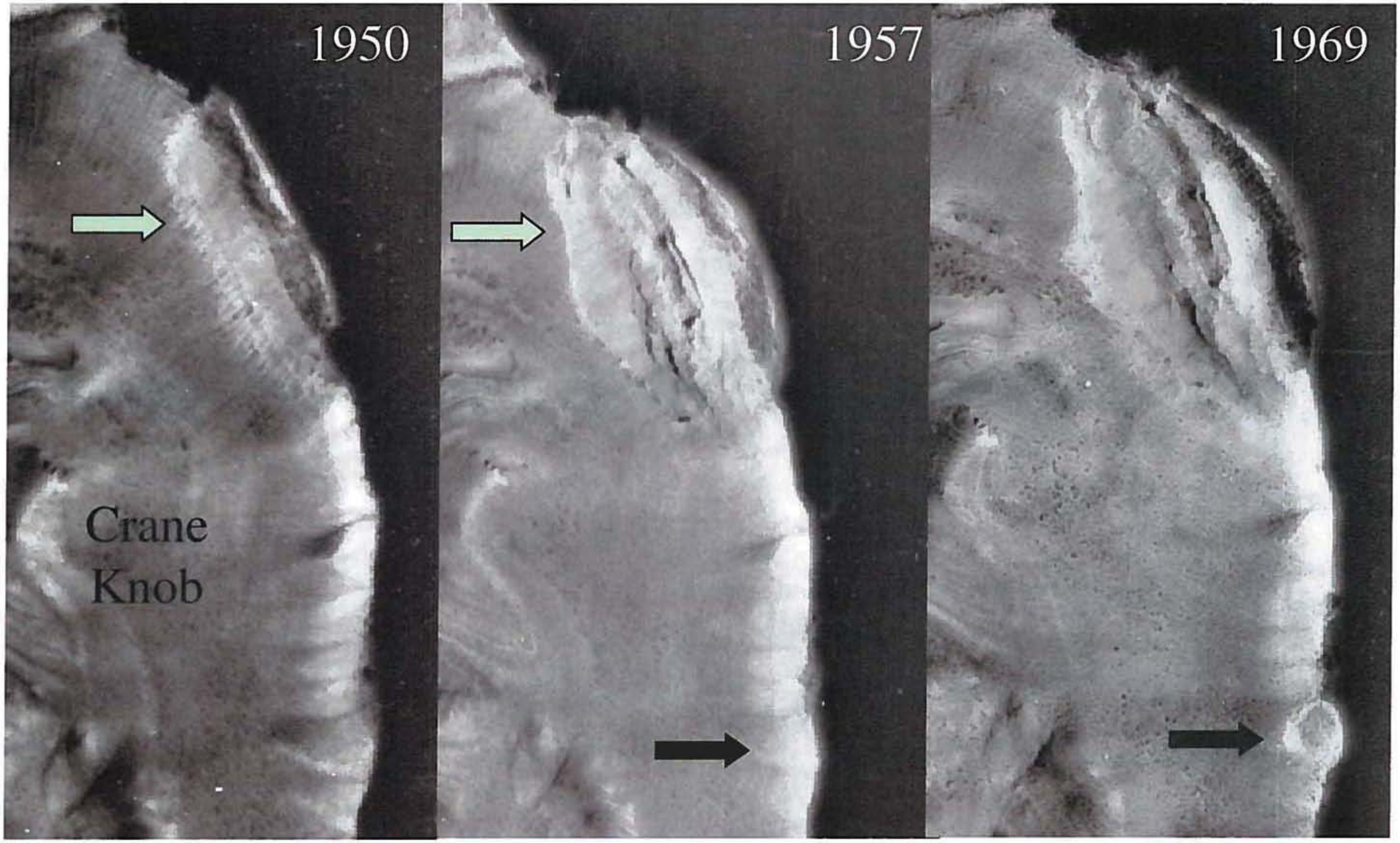
During *early failure stages* tension cracks begin to form as shown on Figs. 9.22 and 9.23. After *partial failure*, in a progressive mode, the slope exists as a series of small slumps and scarps with a toe bulge as shown on Fig. 9.24, or it may rest with a single large scarp and a toe bulge as illustrated on Fig. 9.25. After *total failure*, surface features include various head scarps, concentric and deep tension cracks (Fig. 9.26), and a large mass of incoherent material at the toe (Fig. 9.27). *(See also Fig. 9.21.)*

Slump landforms remaining after total failures provide forewarning of generally unstable slope conditions. They include spoon-shaped irregular landforms, as seen from the air (Figs. 9.28 and 9.29) cylindrical scarps along terraces and water courses *(see Fig. 2.18)*, and hummocky and irregular surfaces, as seen from the ground (Figs. 9.30 and 9.31). In the stereo pair of aerial photos shown in Fig. 9.28, the slump failure mass has stabilized temporarily but probably will reactivate when higher-than-normal seasonal rainfall arrives. A small recent failure scar exists along the road in the center of the slide mass. The rounded features of the mass, resulting from weathering, and vegetation growth indicate that the slide is probably 10 to 15 years old, or more. In the photo, it can be seen that the steep high-

Failure date is c.a. 1954

Translational 'Sheetlike' Movement

Rotational 'Spoonshaped' Movement



Partnership with College of Southern Idaho & IWRRI

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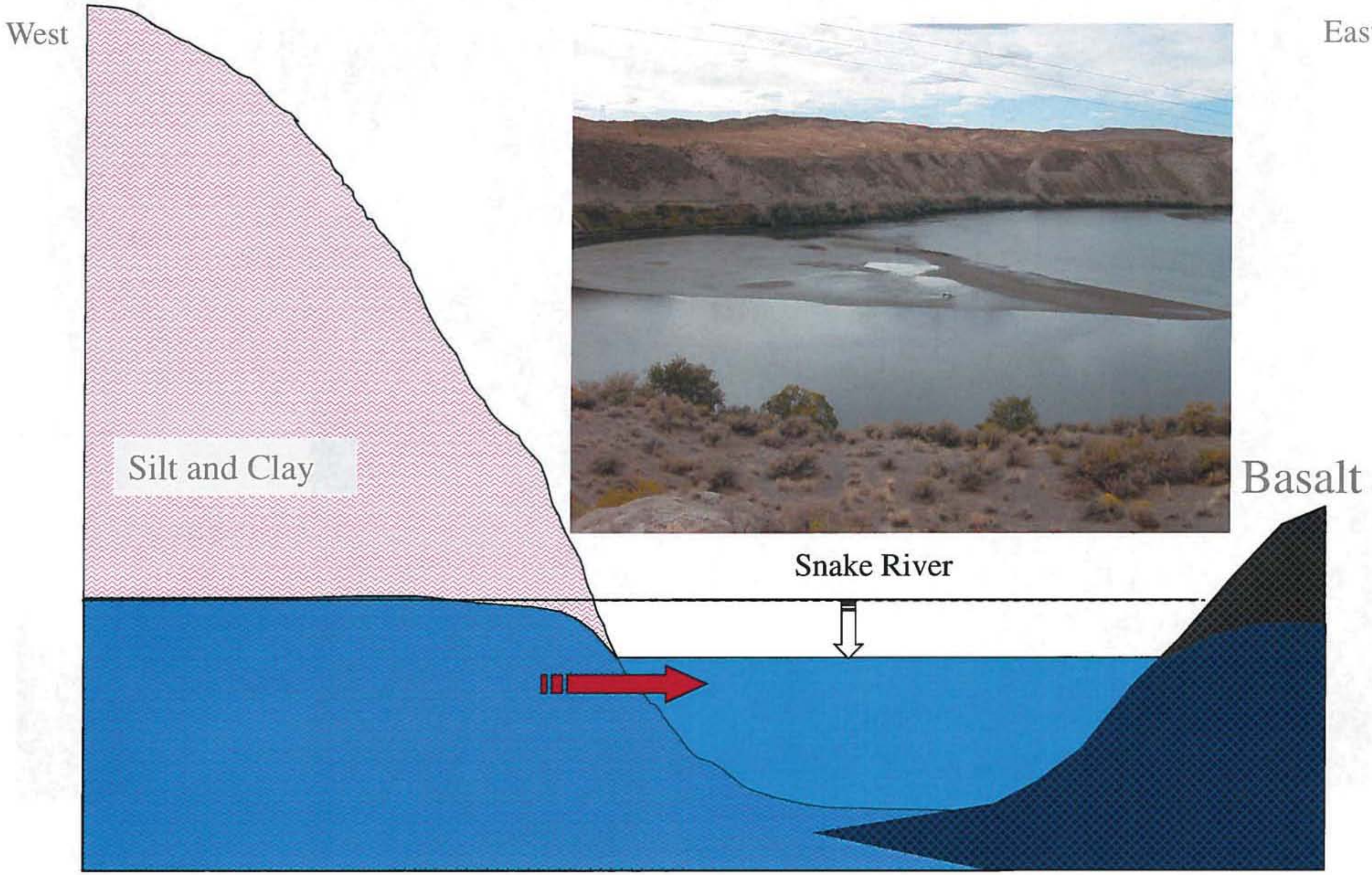
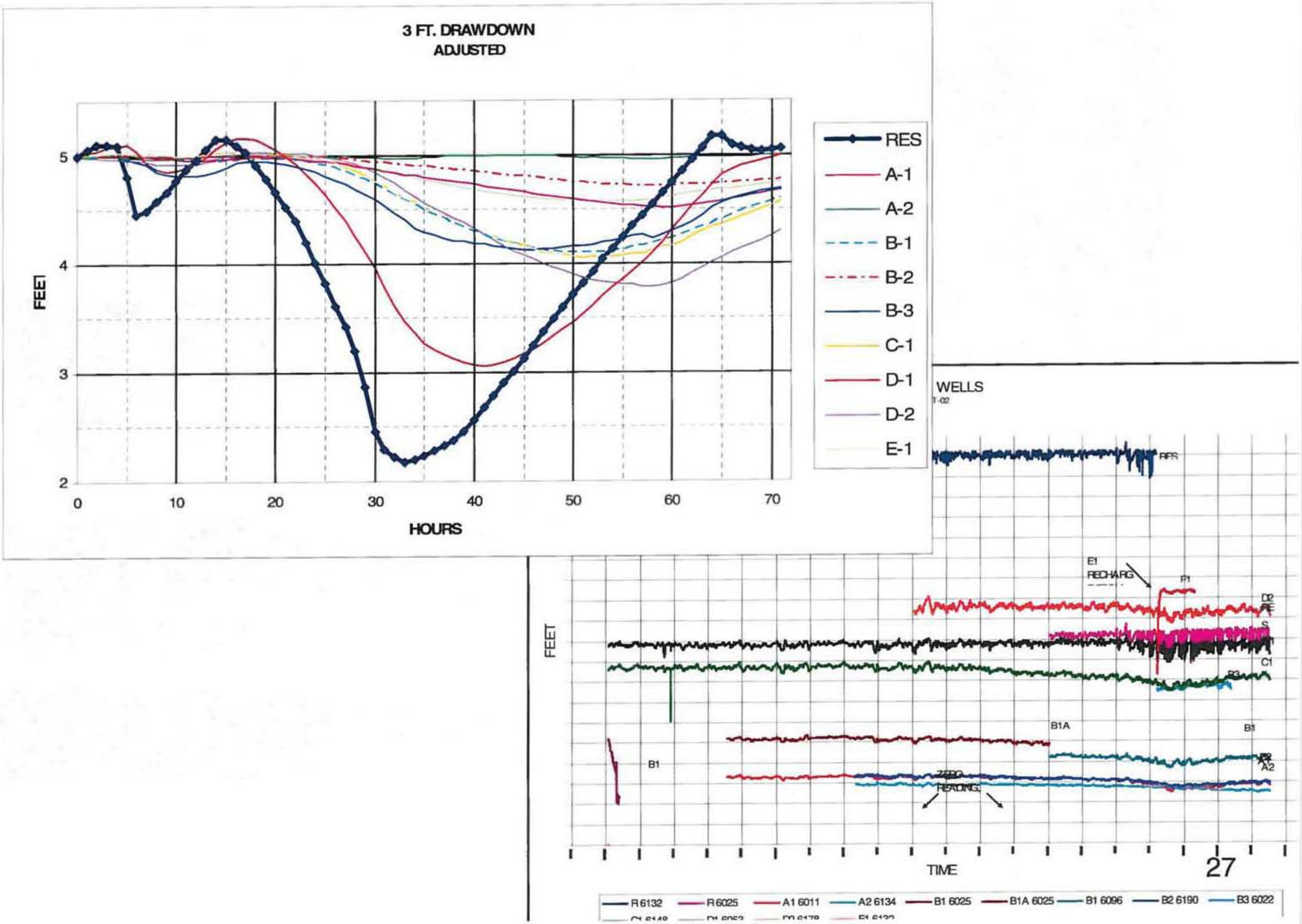
CSI

Groundwater Response to Reservoir Pool Levels

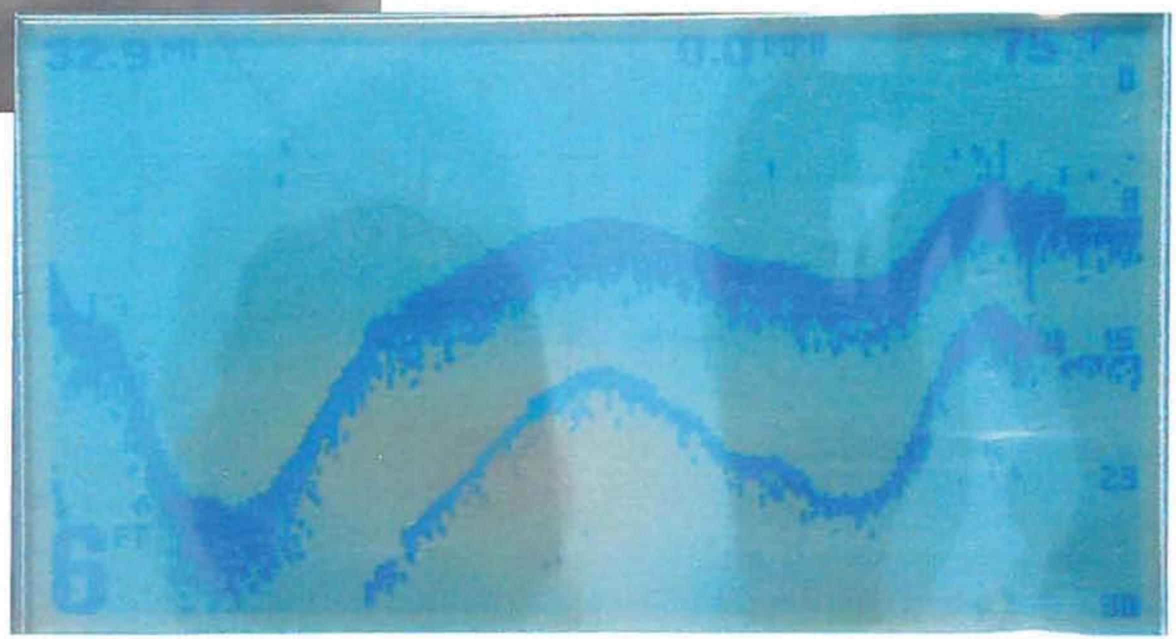


Lower Salmon Falls Reservoir Drawdown Data



Lower Salmon Falls Reservoir Sediments

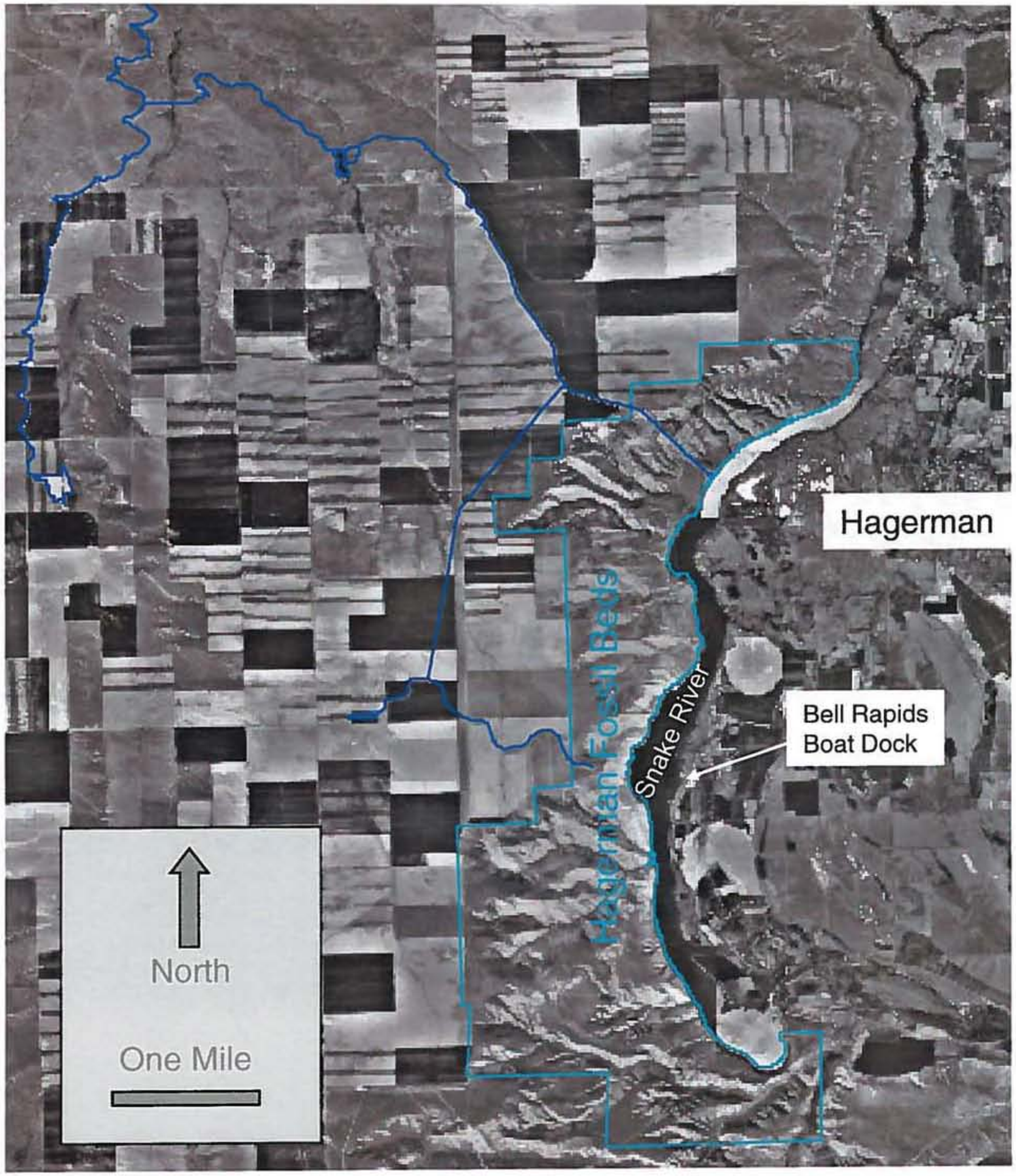
Sediments de-gassing during a reservoir drawdown event.



Depth of sediments is interpreted to be about 7 feet over approximately 50 year period or about 1.5 inches per year. So, if the rate continues, in 50 years the shallow flats will be at normal reservoir pool level.

Bell Rapids Project

- 1st irrigation season in 1970
- Last irrigation season in 2004
- 1st landslide associated with perched aquifers in ~ 1979
- originally ~ 25,000 acres
- Ave. annual water usage ~45,000 ac-ft.
- pressurized irrigation only
- 300 miles of pipeline
- originanlly 2 pump stations on river
- 1987 landslide destroyed one station
- canal leakage tests range from 10 to 20 percent.
- Project shutdown in year 2005



Perched Aquifer Growth Timeline

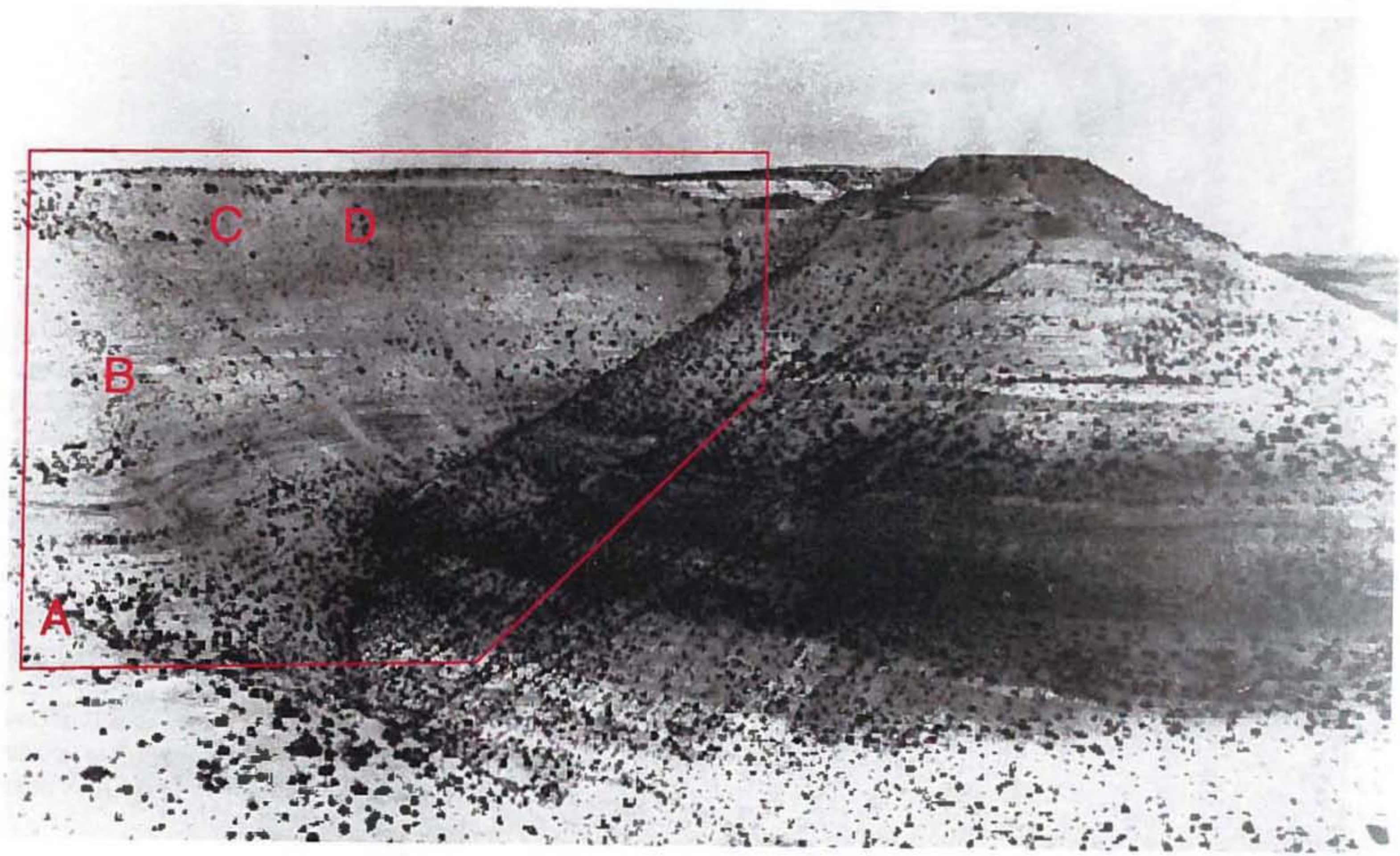


Photo from
the 1930's

Impacts From Land Use Change

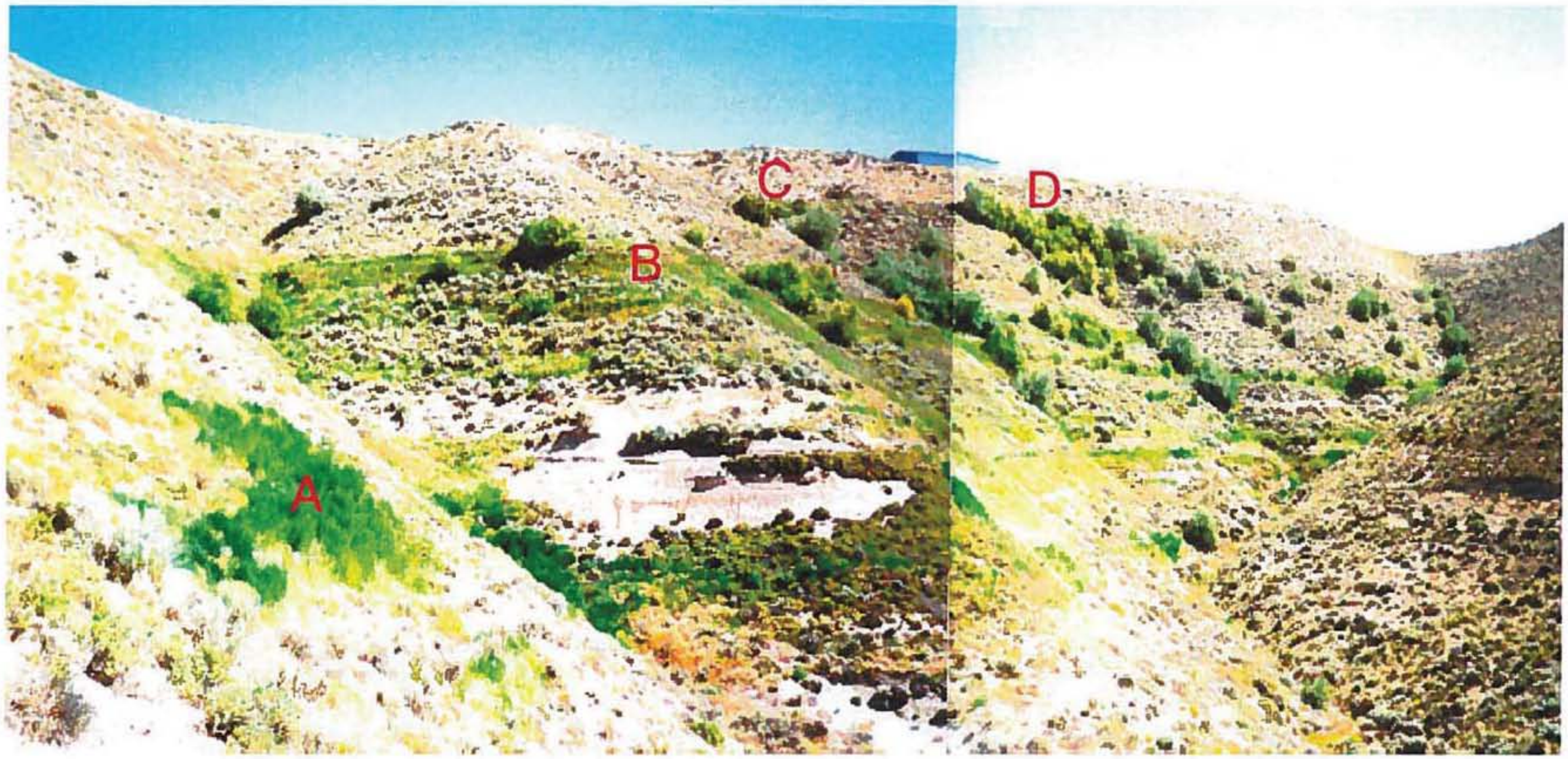


Photo year - 1997

(photo by Neal Farmer, 1997)

Impacts From Land Use Change

Photo year 1974

Impacts From Land Use Change

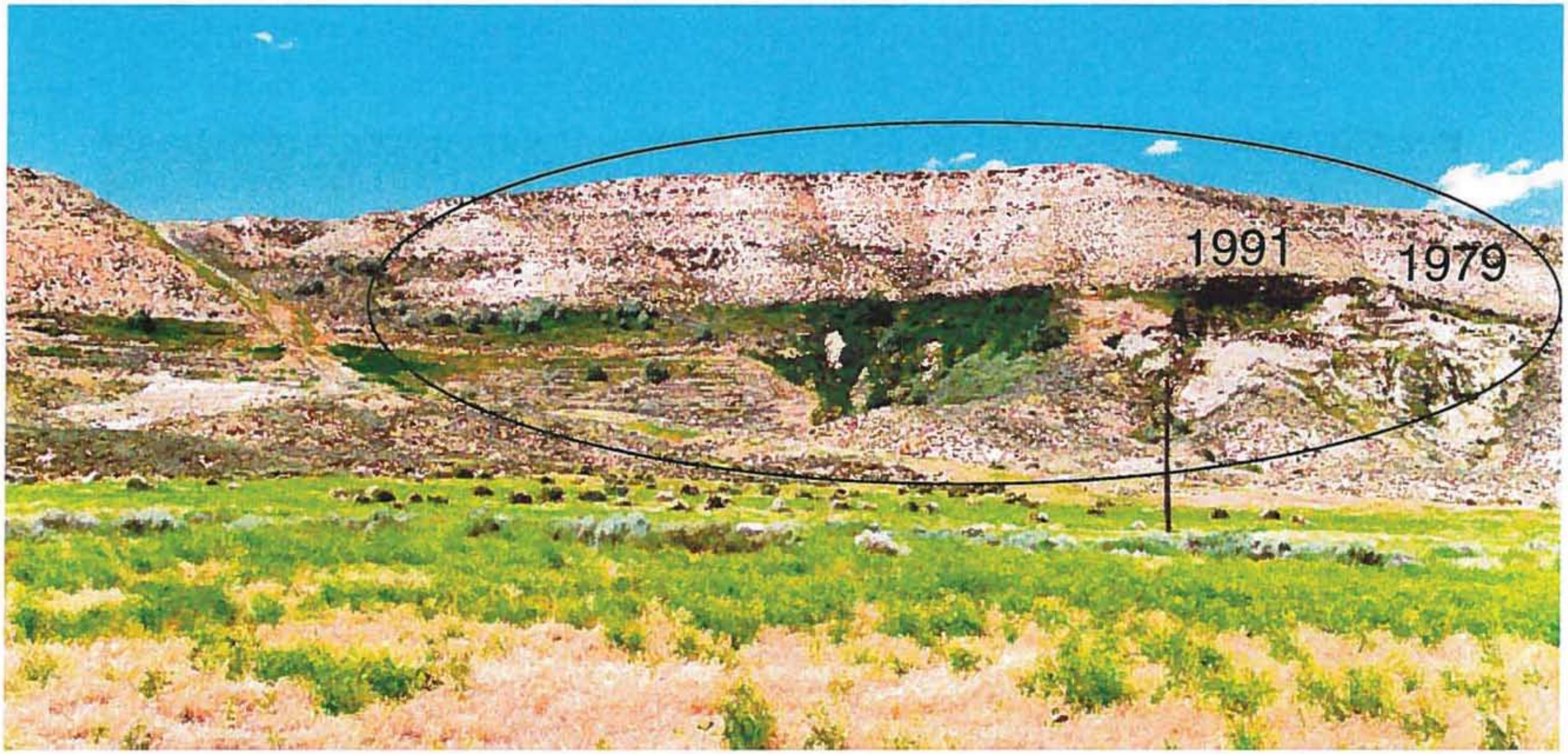
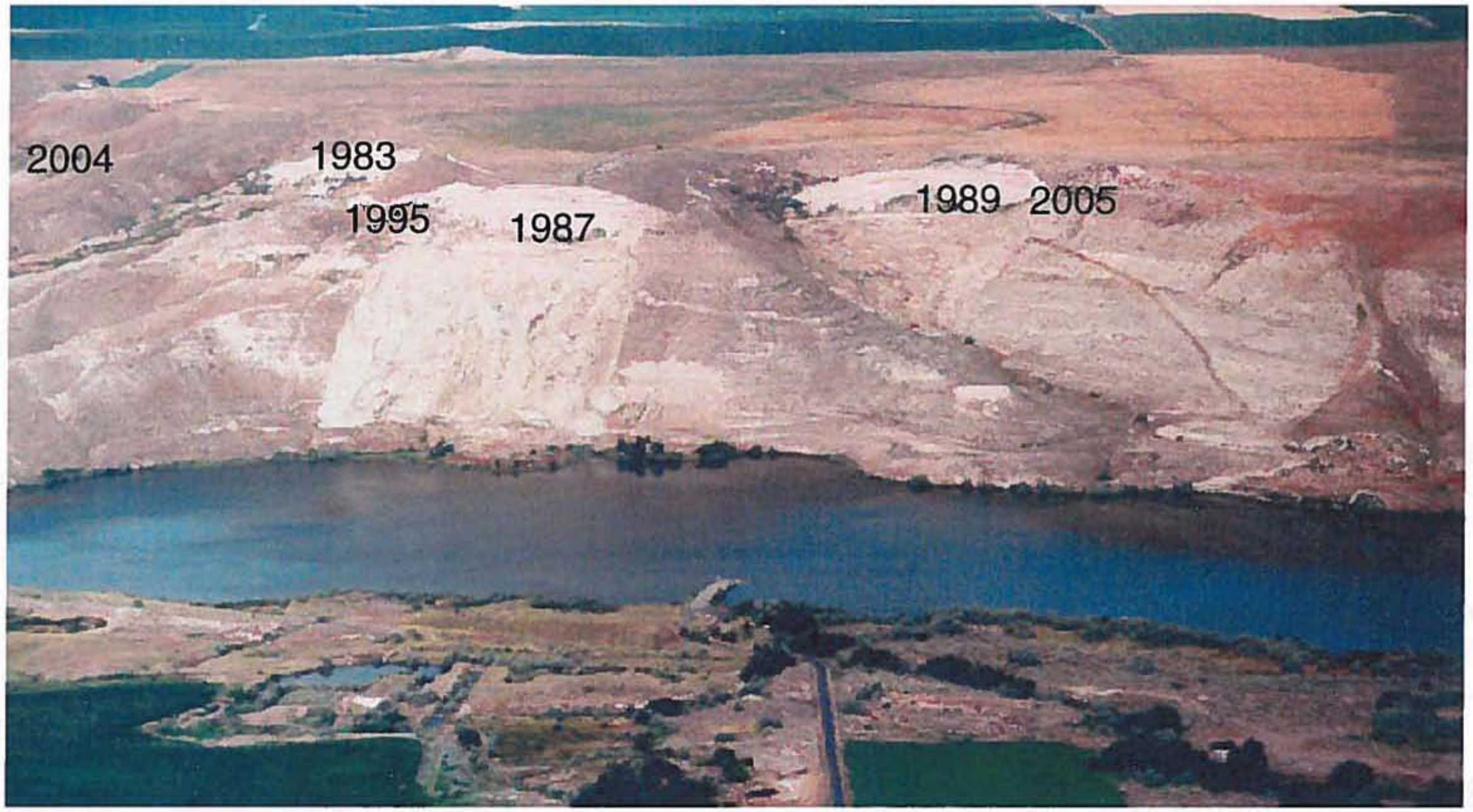


Photo year 1997

(photo by Neal Farmer 1997)

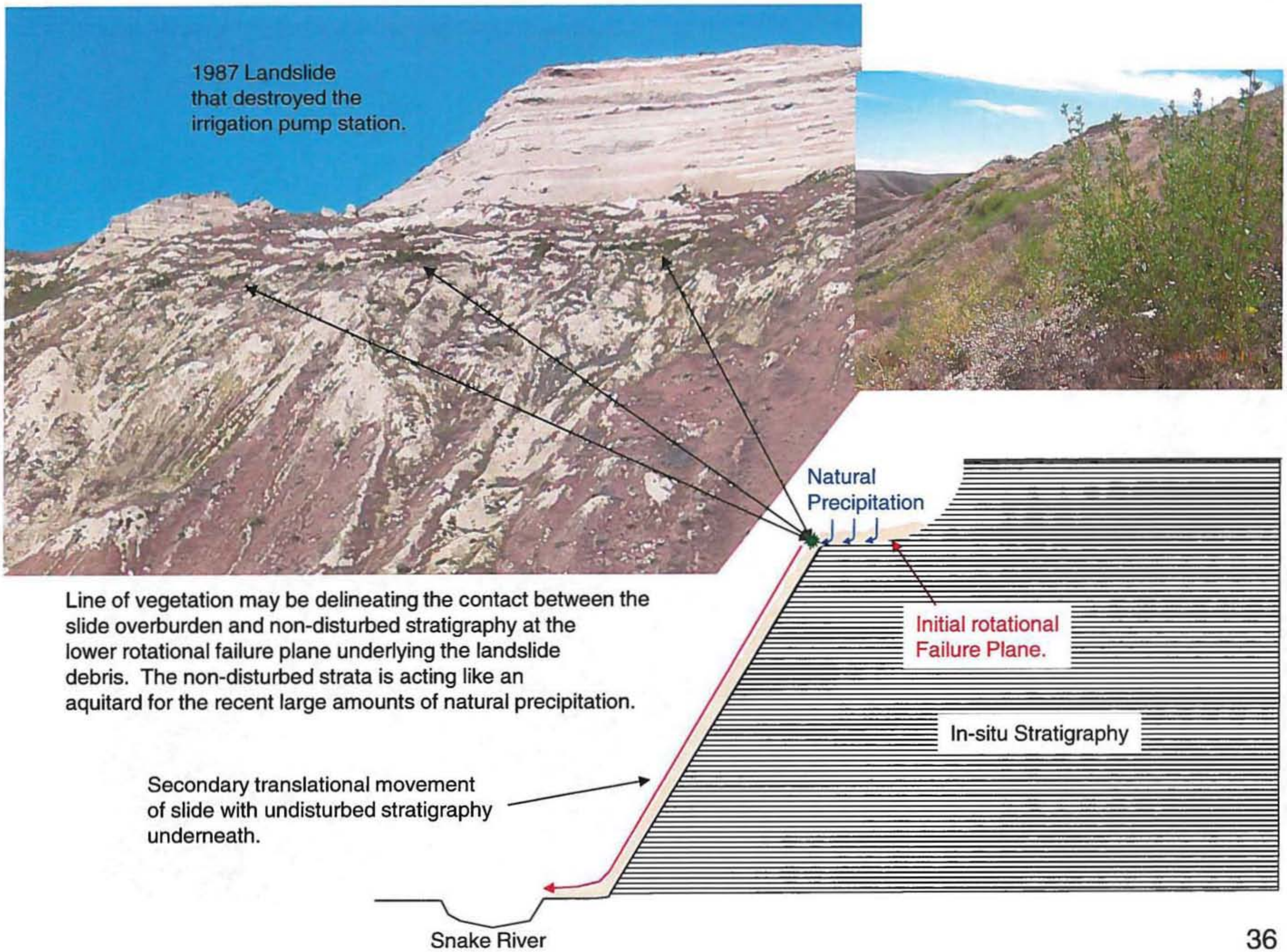
Impacts From Land Use Change



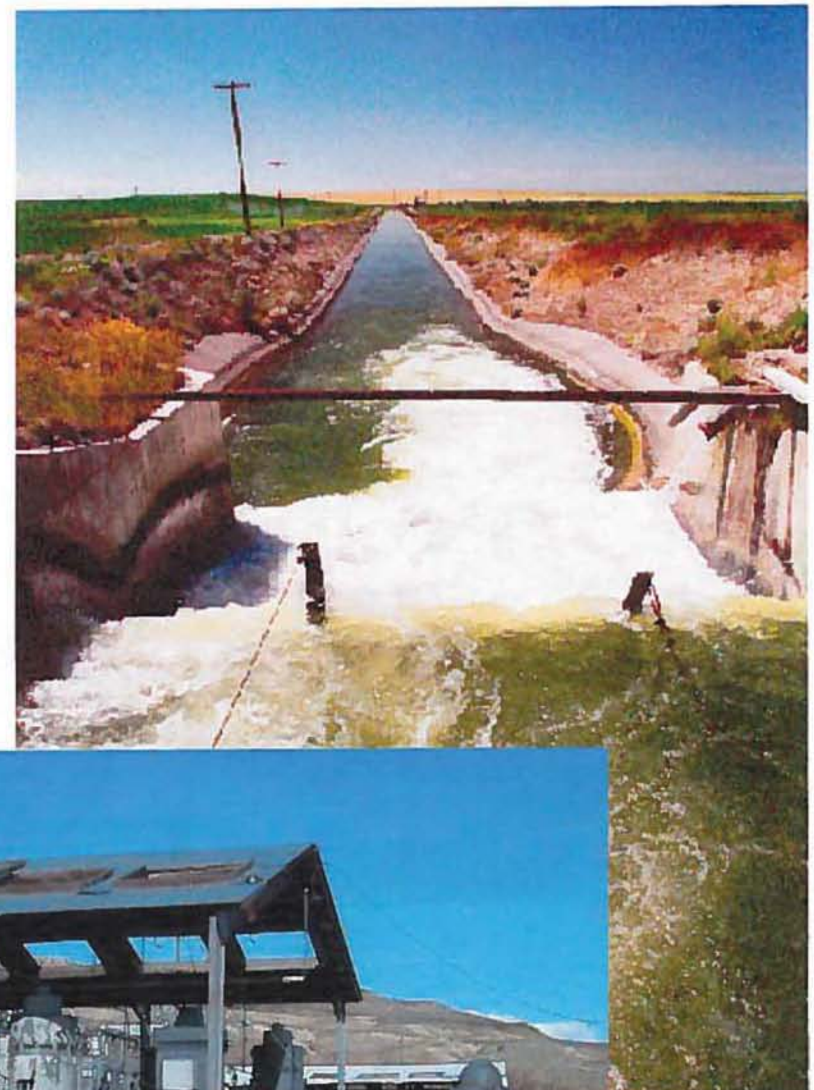
Impacts From Land Use Change

1950

1997

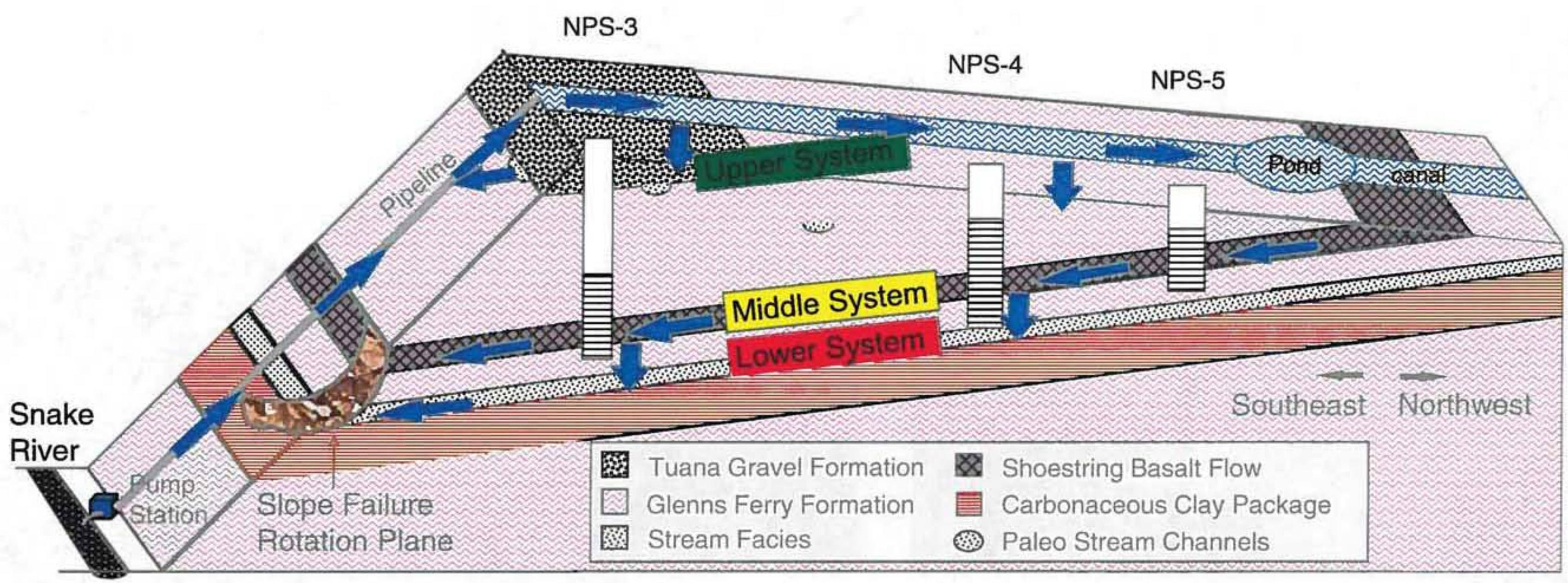

1987 Landslide
that destroyed the
irrigation pump station.
Natural
Precipitation
Initial rotational
Failure Plane.
Line of vegetation may be delineating the contact between the slide overburden and non-disturbed stratigraphy at the lower rotational failure plane underlying the landslide debris. The non-disturbed strata is acting like an aquitard for the recent large amounts of natural precipitation.
In-situ Stratigraphy
Secondary translational movement
of slide with undisturbed stratigraphy
underneath.
Snake River

Fossil Gulch Pumping Station and Canal

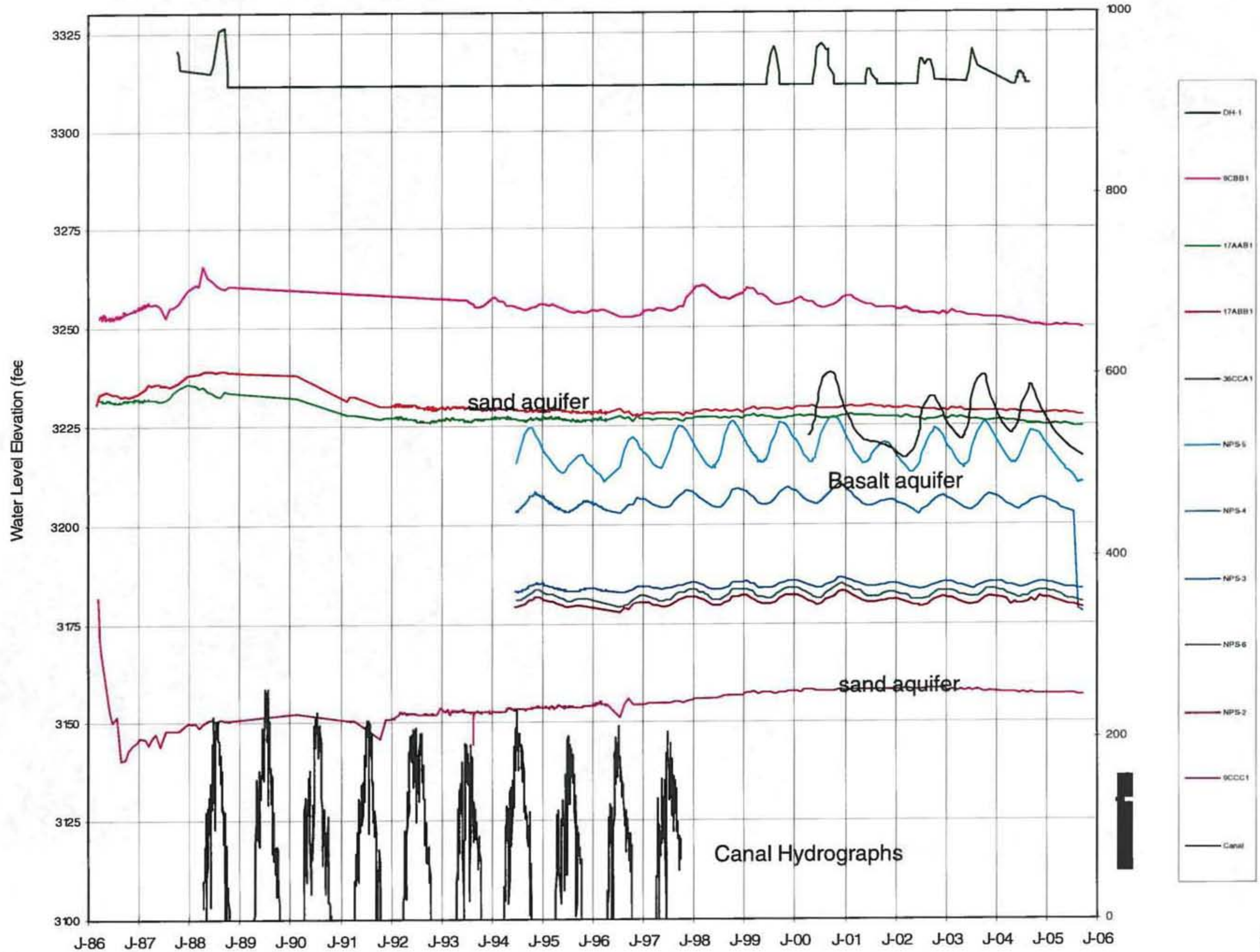


- Maximum delivery rate exceeded 120,000 g.p.m.
- Each pump = 9,000 g.p.m.
- Each electric motor = 10,000 h.p.
- 3 pipelines up hillside to plateau
- In July 2004 electric costs was ~ $180,000

Hydrostratigraphic Block Model



Perched Aquifer Groundwater Hydrographs



Partnership with University of Idaho and Idaho Water Resources Research Institute

University of Idaho

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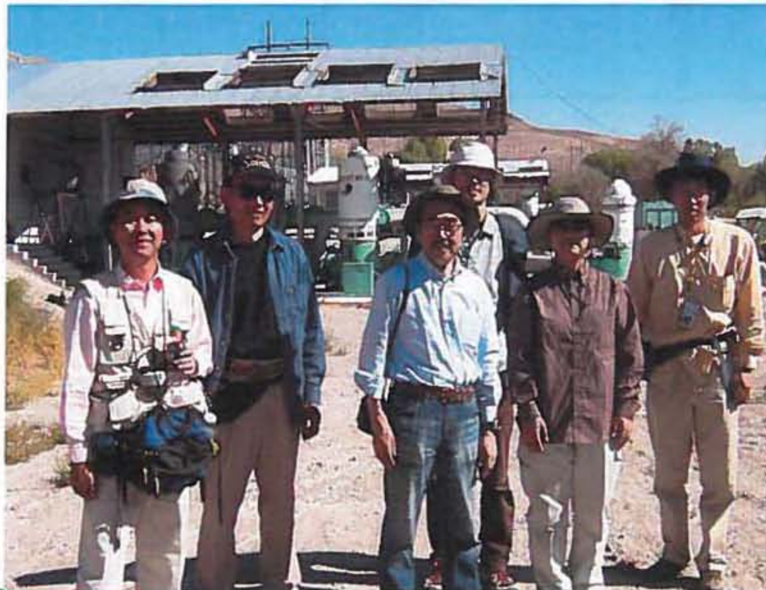
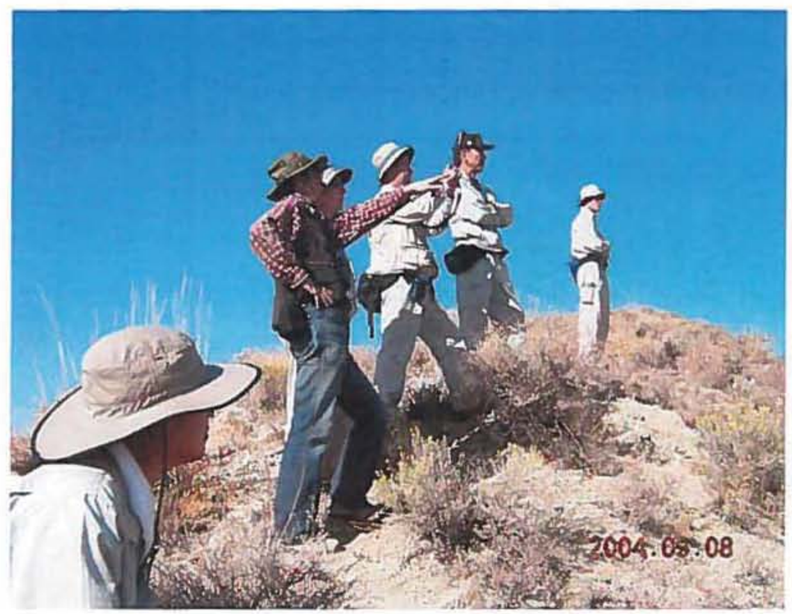
International Partnership with Japan Landslide Scientists



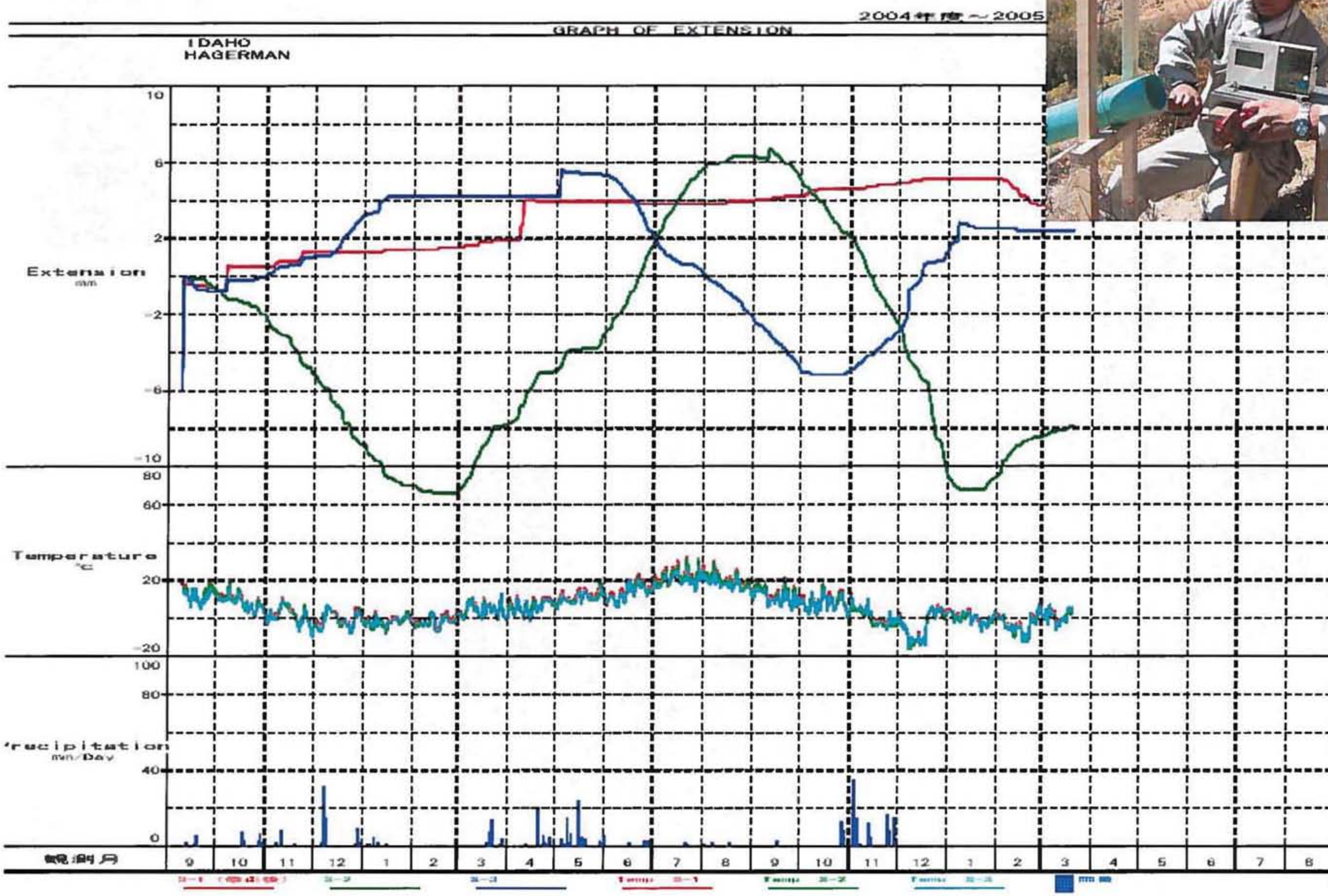
Hagerman


ニュース／国際部
World News

土地利用変化により発生した地すべりと危機にさらされる人命と自然・文化資源
Hagerman Valley化石床国立モニュメント，アイダホ



International Partnership with Japan Landslide Scientists



Natural Tracers Research Partnership with UofI and IWRRI

University of Idaho

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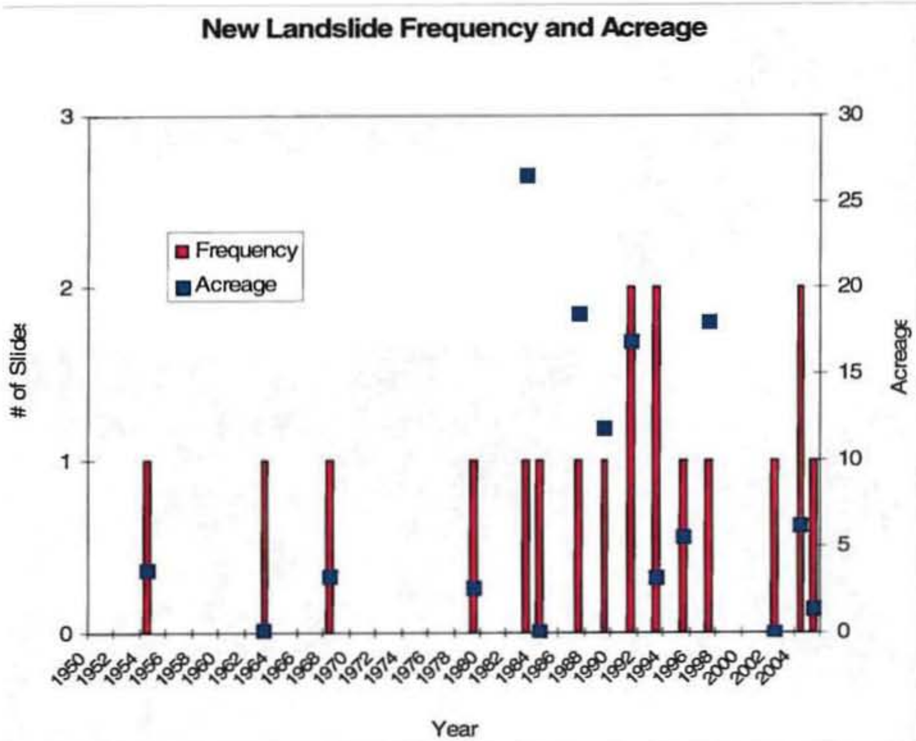
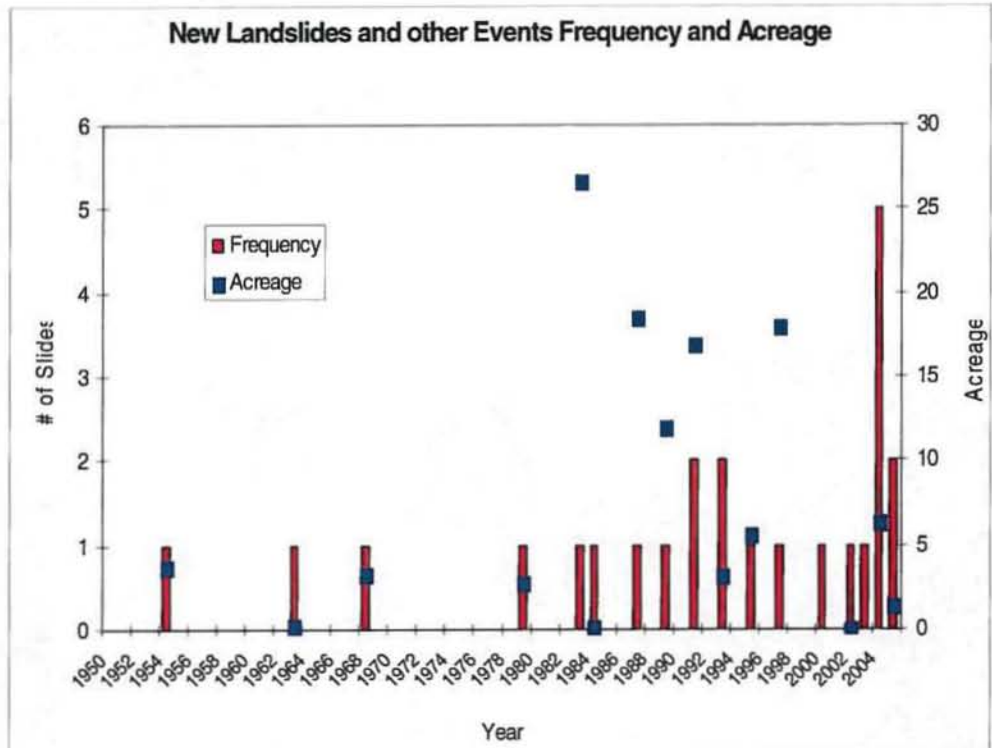
Histogram of Landslide Events





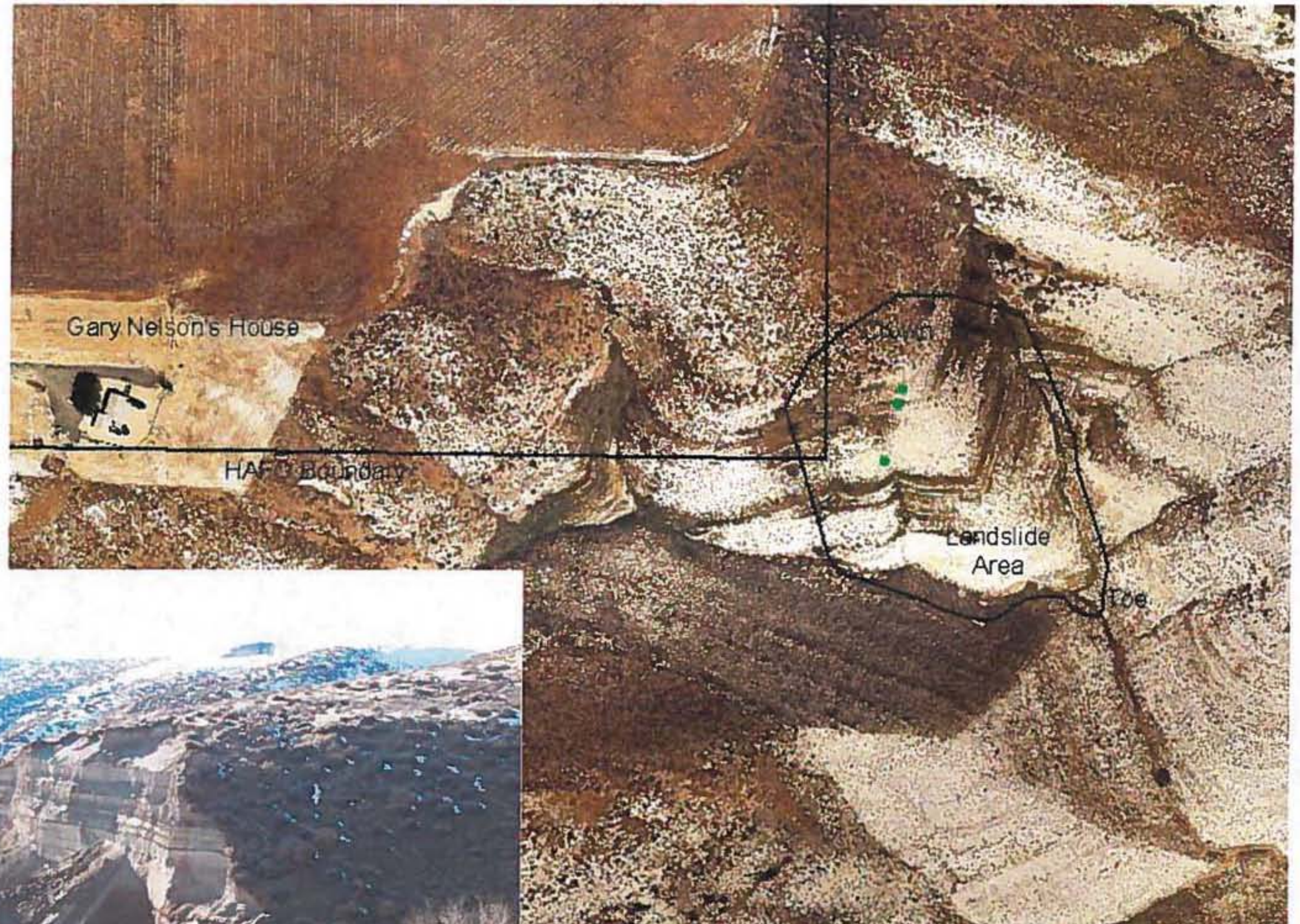
2004 Landslide

Photo year 1995

Apparent Initial slip surface or shear zone.

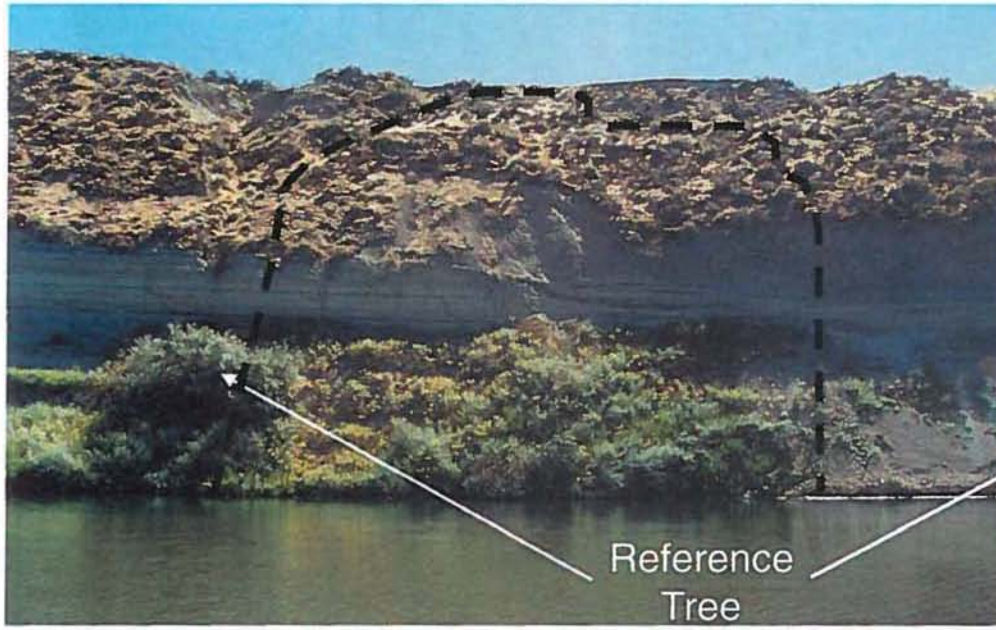
Paleo stream sand channel discharging groundwater.

Area of 2004 Landslide

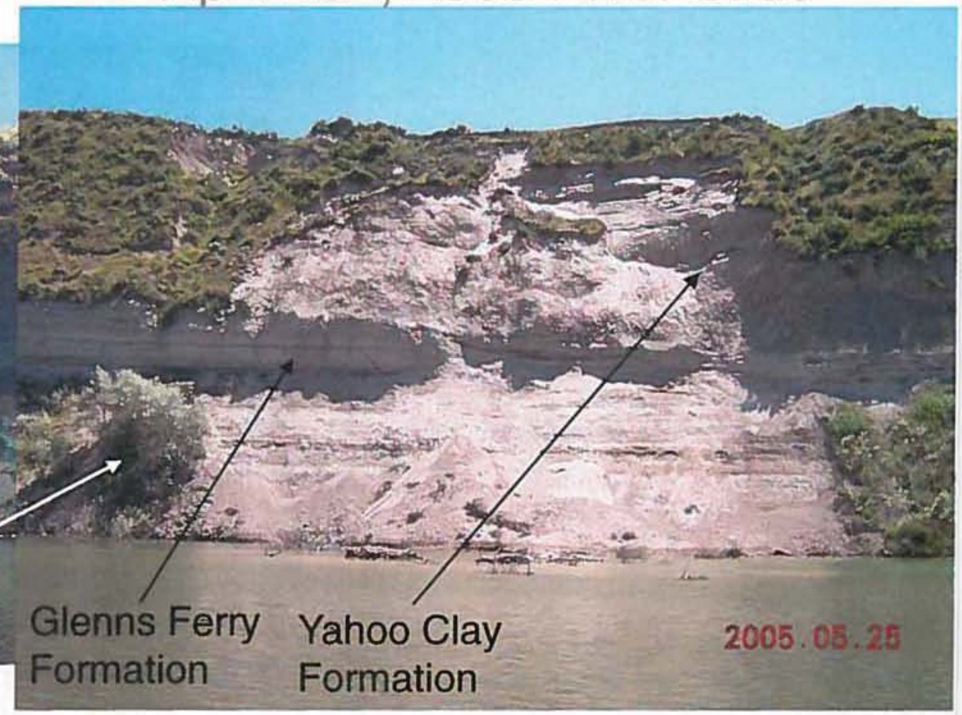


Landslide Events

Photo from year 2001



April 28th, 2005 River Slide



Landslide Events

Air Photo year 2001

June 2005 photo

Landslide Events

Recent Landslide Events

1989 landslide Reactivation

Area that failed between
October 13 and
October 19, 2005.

Fracture in
Oct. 19th photo
but not on 13th.

Fresh scarp of Oct. 19th
photo but not in Oct. 13th.

Distance is about 25 – 30 meters.

1989 landslide sat dormant for 16 years then reactivated with a headwall scarp failure in year 2005. The failure started on the north edge and progressively failed in sections across the headwall scarp right to left (south) edge.

Impacts From Land Use Change

References:

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Malde, H.E., 1972, Geologic Map of the Glenns Ferry-Hagerman Area, west-central Snake River Plain, Idaho, U.S. Geological Survey Miscellaneous Investigations Map I-169, scale 1:48,000, 2 sheets.

Middleton, L. T., 1976, Depositional environments of the Glenns Ferry Formation near Jackass Butte, Idaho: Unpublished M.S. Thesis, Idaho State University, 58 p.

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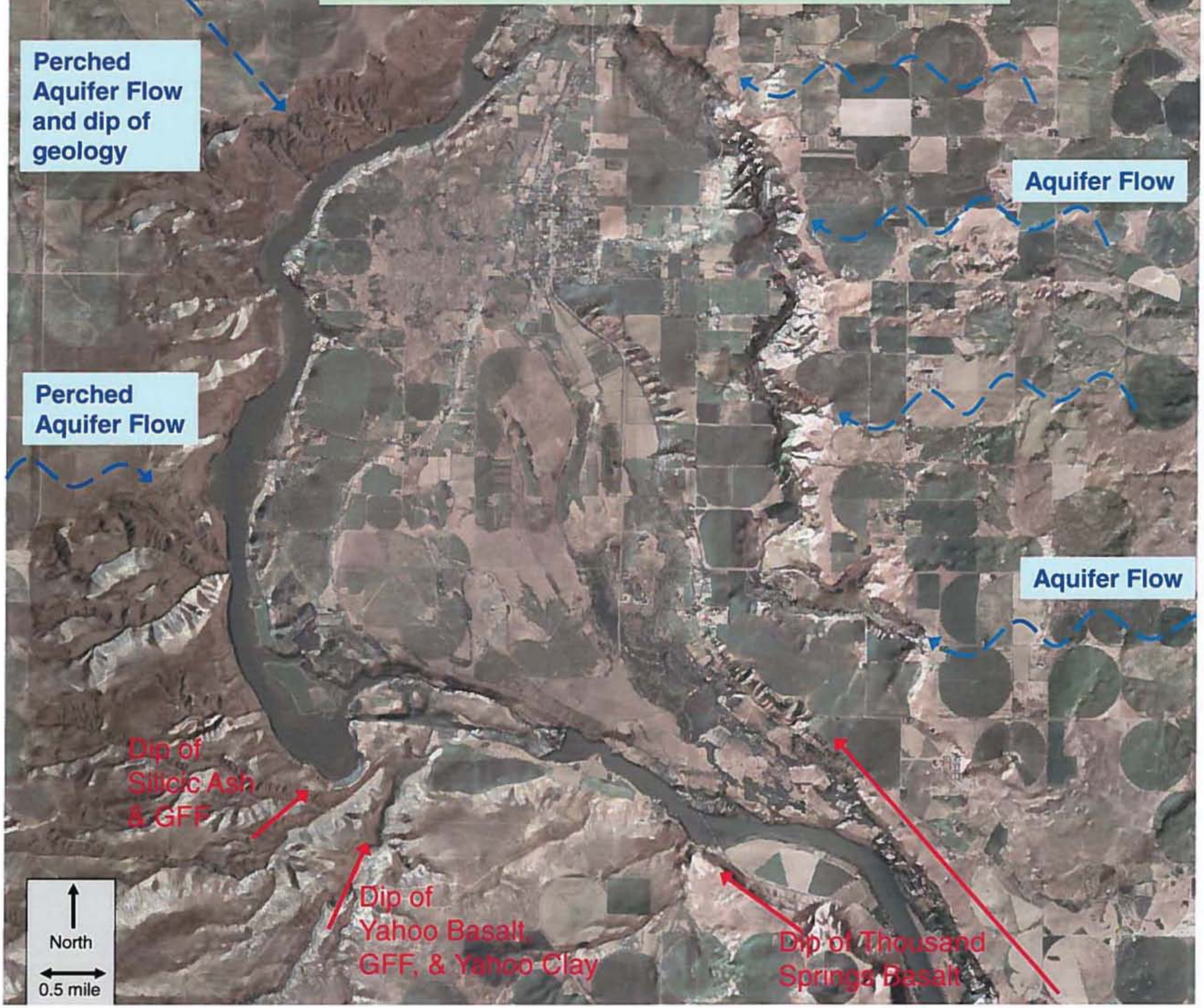
Tucker, M.E., 1991, Sedimentary Petrology; An Introduction to the origin of sedimentary rocks: Blackwell Scientific Publications, 260 p.

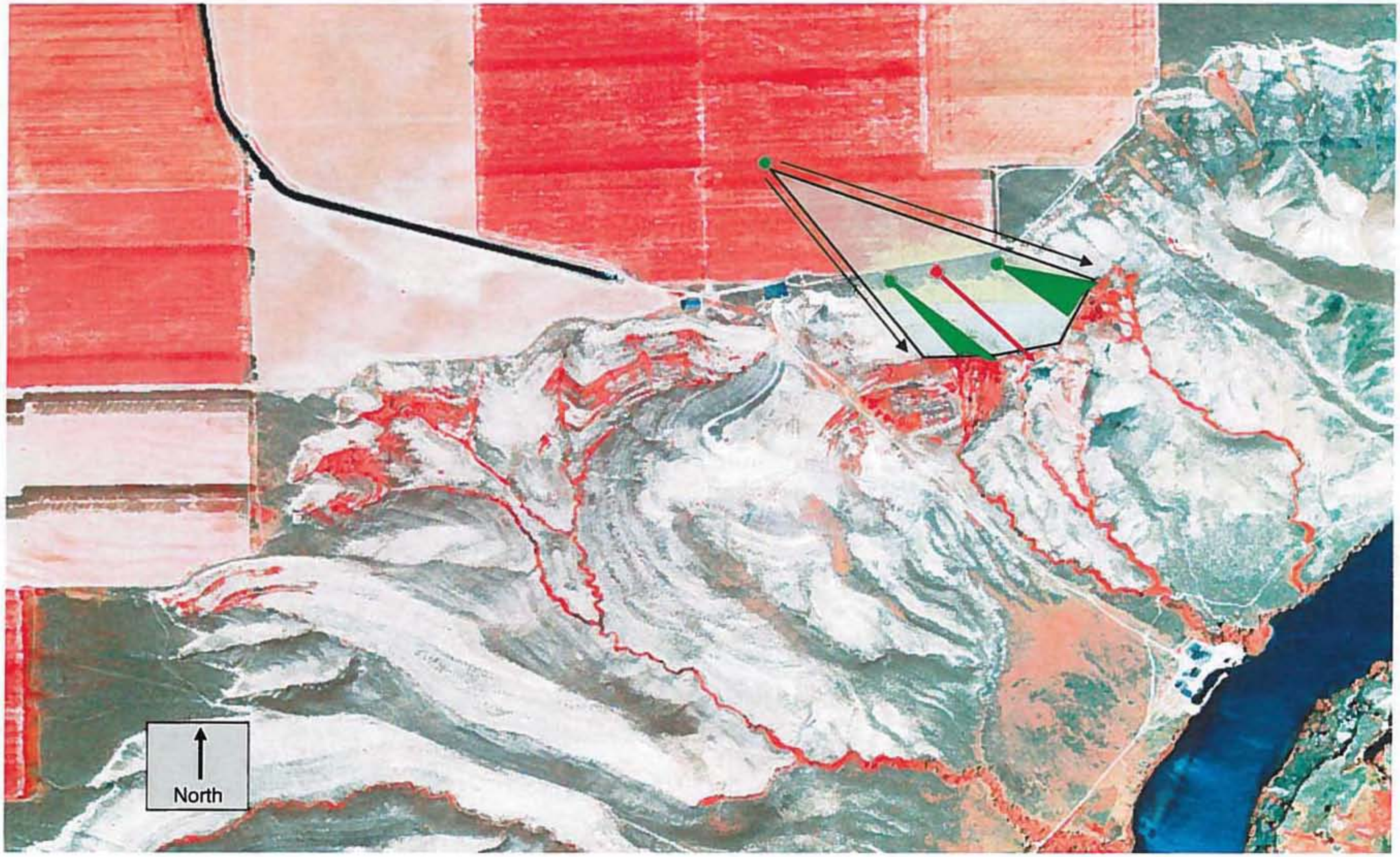
Yahoo Gulch Stop

Geologic Dips and Groundwater Flow Direction



Flourescent dye groundwater tracer tests document direction of groundwater flow is to southeast at up to 250 feet per day in Tertiary age 'brown' basalt, sometimes thought to have low permeability.

Surveyed geologic outcrops and well logs in this area support a southeast dipping architecture with in the lake sediments.



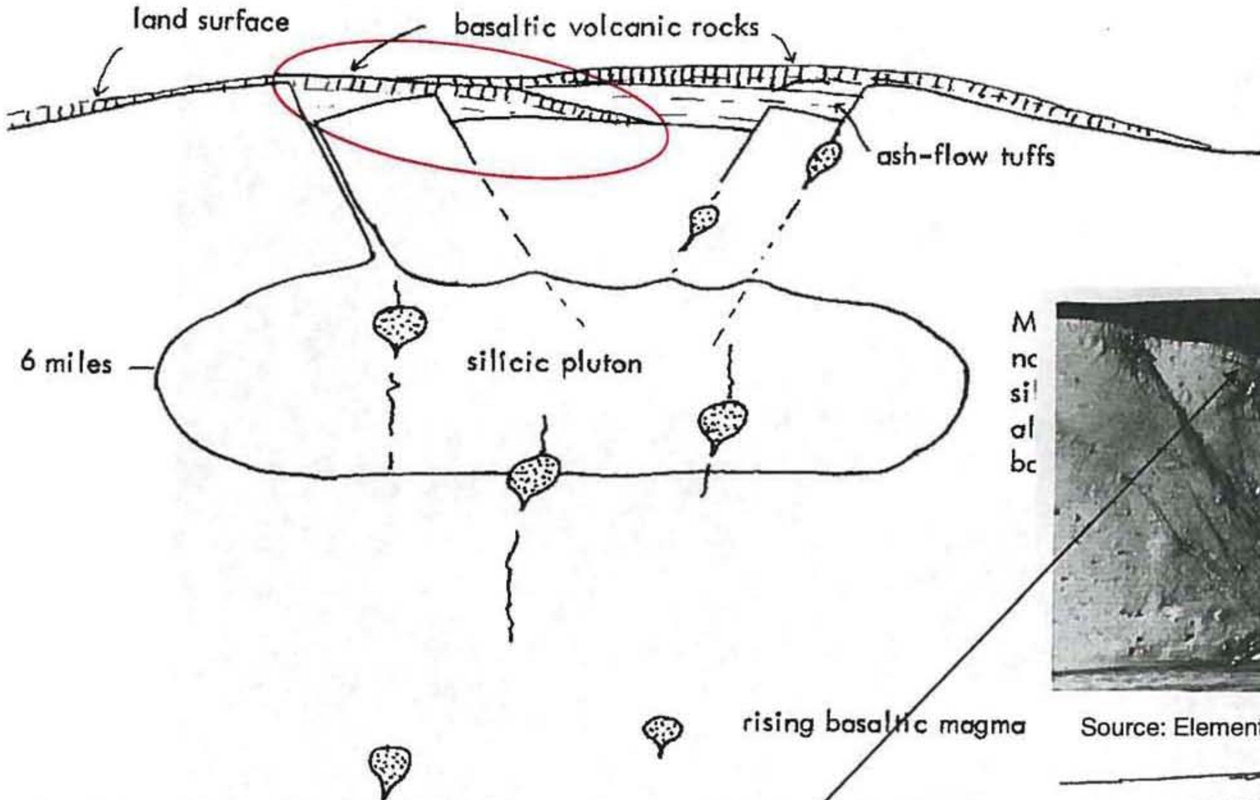
Flourescent Dye Groundwater Tracer Tests

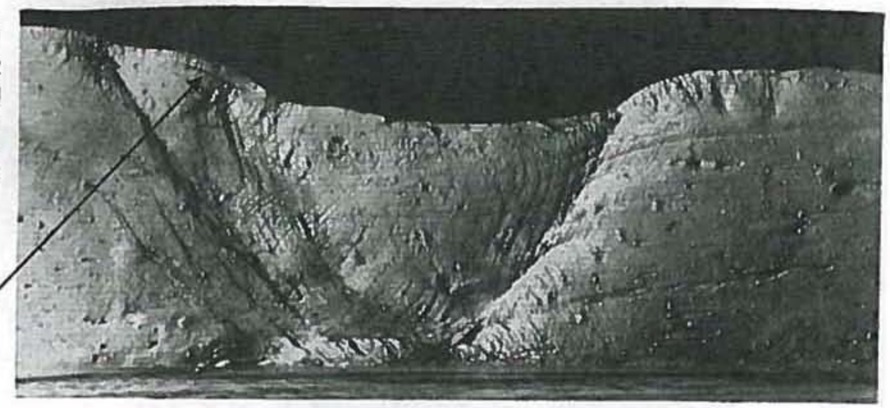
Northerly Dipping Ash Interbedded within Glenns Ferry Fm. Lake Sediments

(view azimuth is west)

Idealized Caldera Collapse Structure as a Possible Model

(from Terry Maley 'Exploring Idaho Geology', 1987)





Source: Elements of Structural Geology by E. Sherbon Hills, 1972, 502 p.

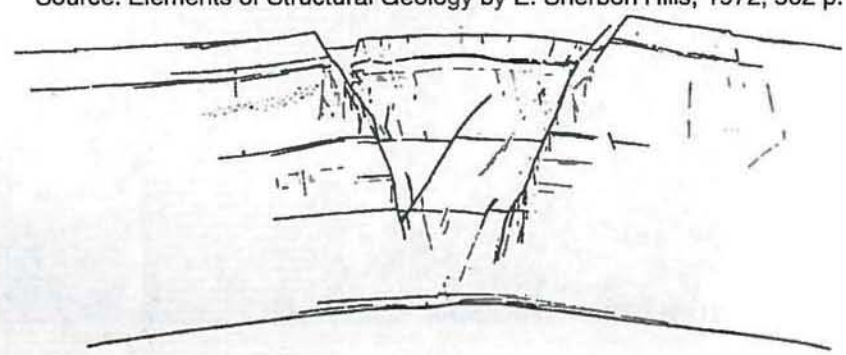


FIG. VII–28. EXPERIMENTAL GRABENS

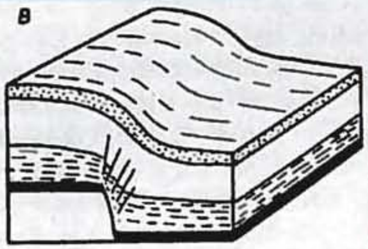
A. Produced in a cake of clay subjected to tension.

B. Produced in a cake of clay arched over a balloon. (*After H. Cloos*)

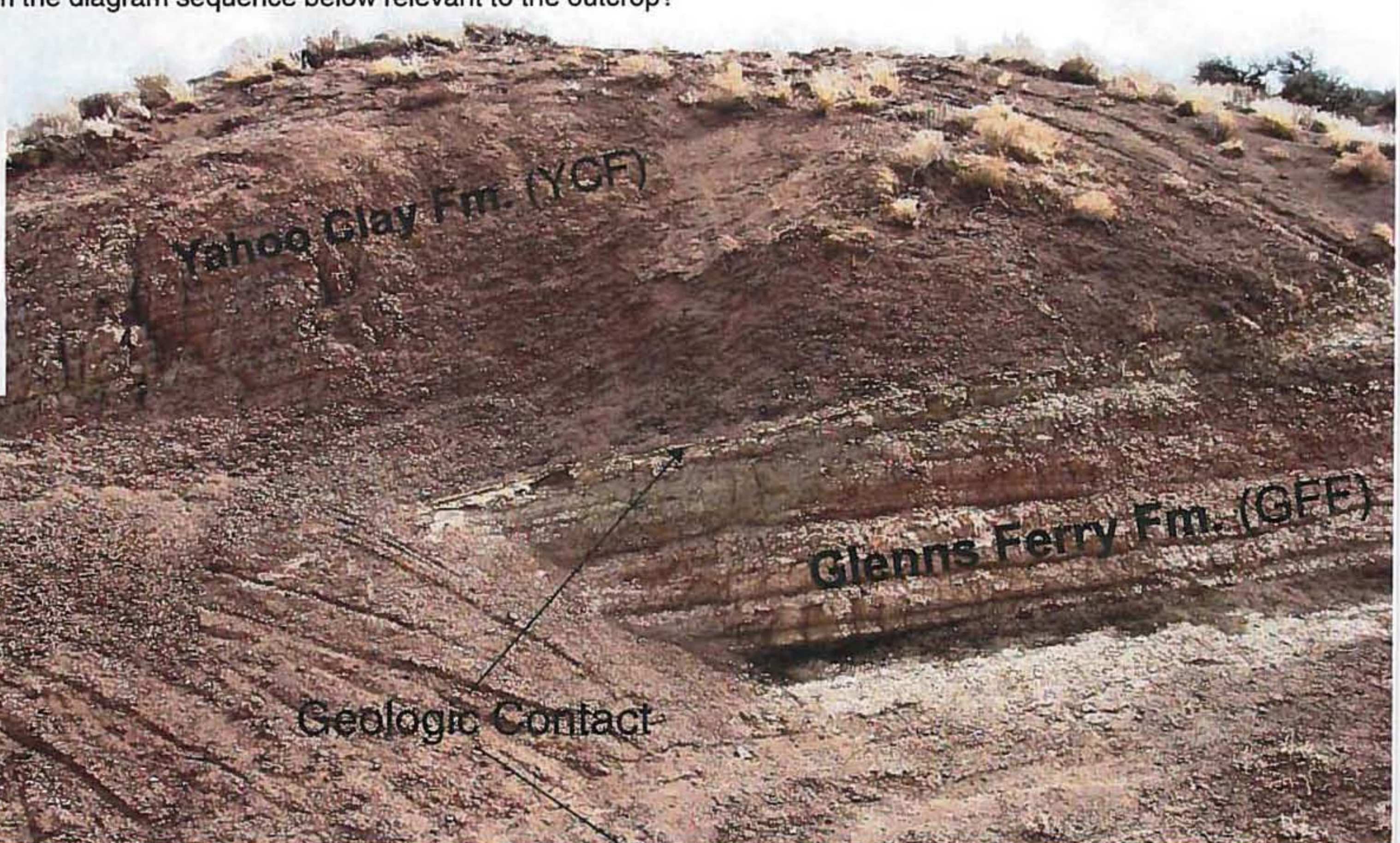
North Dipping Yahoo Clay Fm. on top of North Dipping Monocline of the Glenns Ferry Fm.

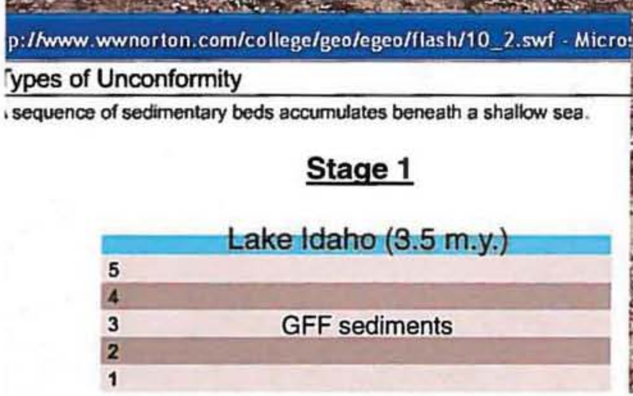
(view azimuth is east and location is Yahoo Creek)

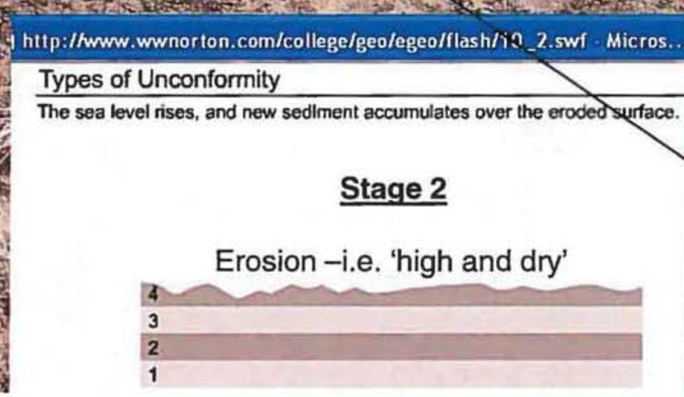
- What "**Stage**" is missing from the diagram sequence below relevant to the outcrop?

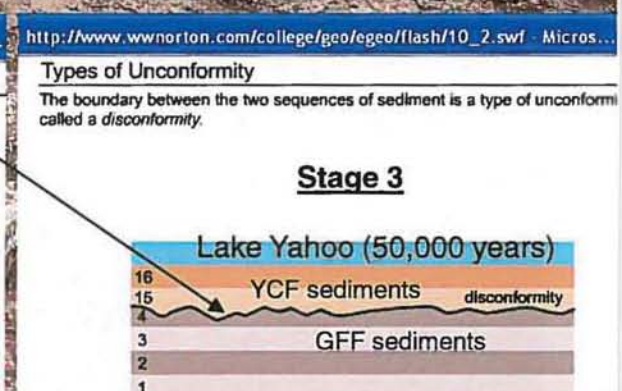


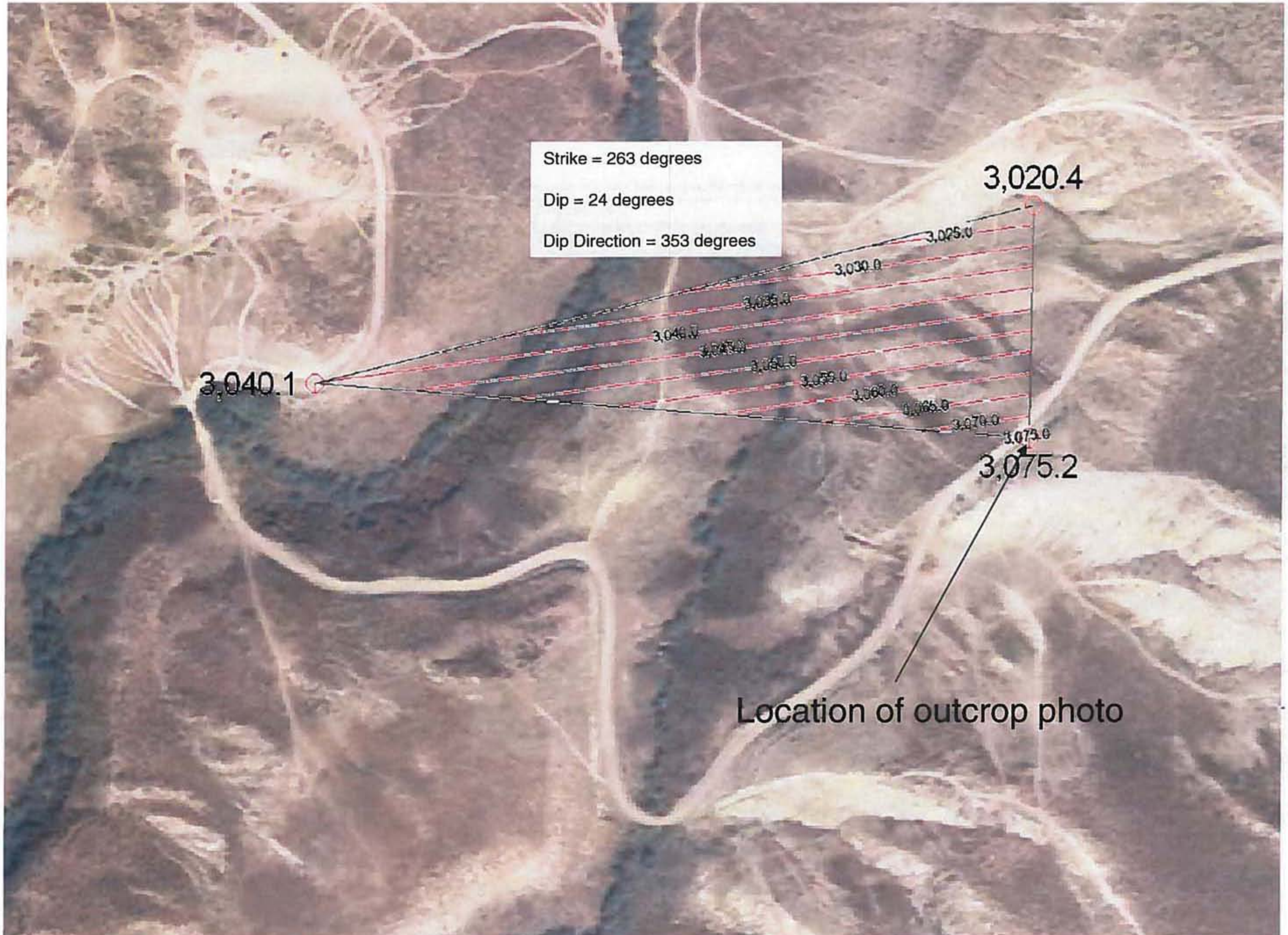
(Source: Elements of Structural Geology by E. Sherbon Hills, 1972, 502 p.)



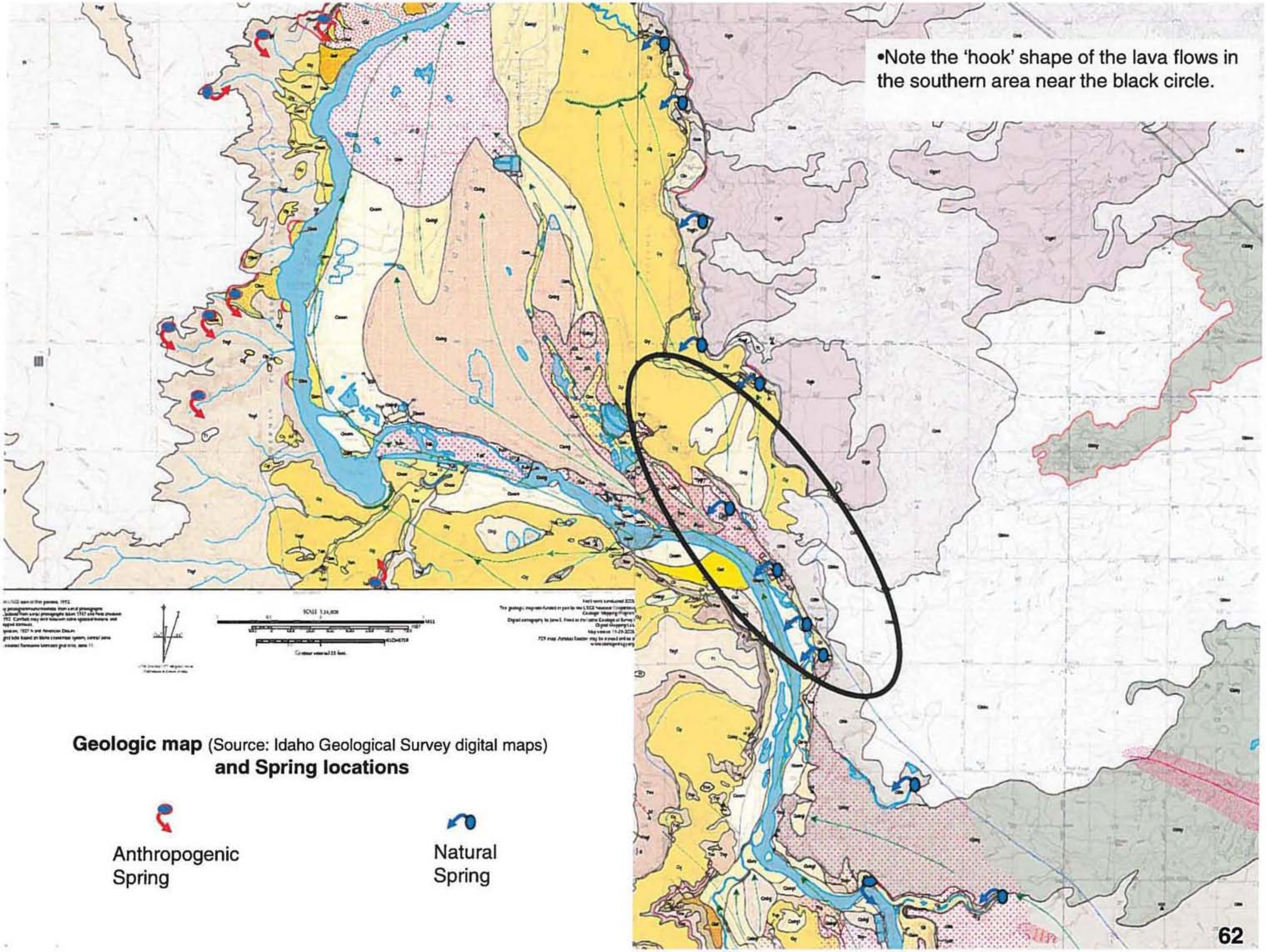







Strike = 263 degrees
Dip = 24 degrees
Dip Direction = 353 degrees
3,020.4
3,040.1
3,075.2
Location of outcrop photo

Sligars Stop

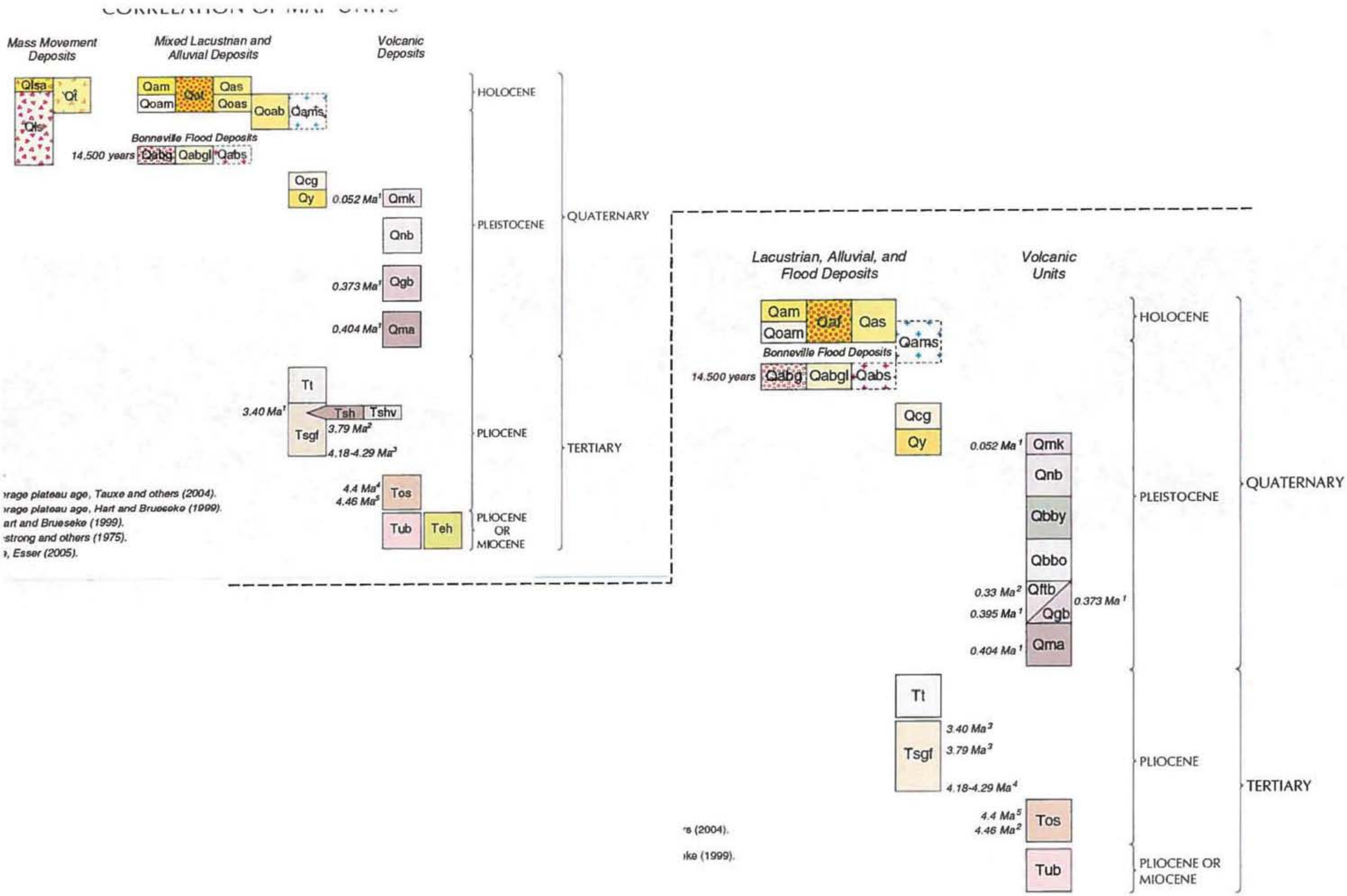


•Note the 'hook' shape of the lava flows in the southern area near the black circle.

Geologic map (Source: Idaho Geological Survey digital maps)
and Spring locations

Anthropogenic Spring

Natural Spring



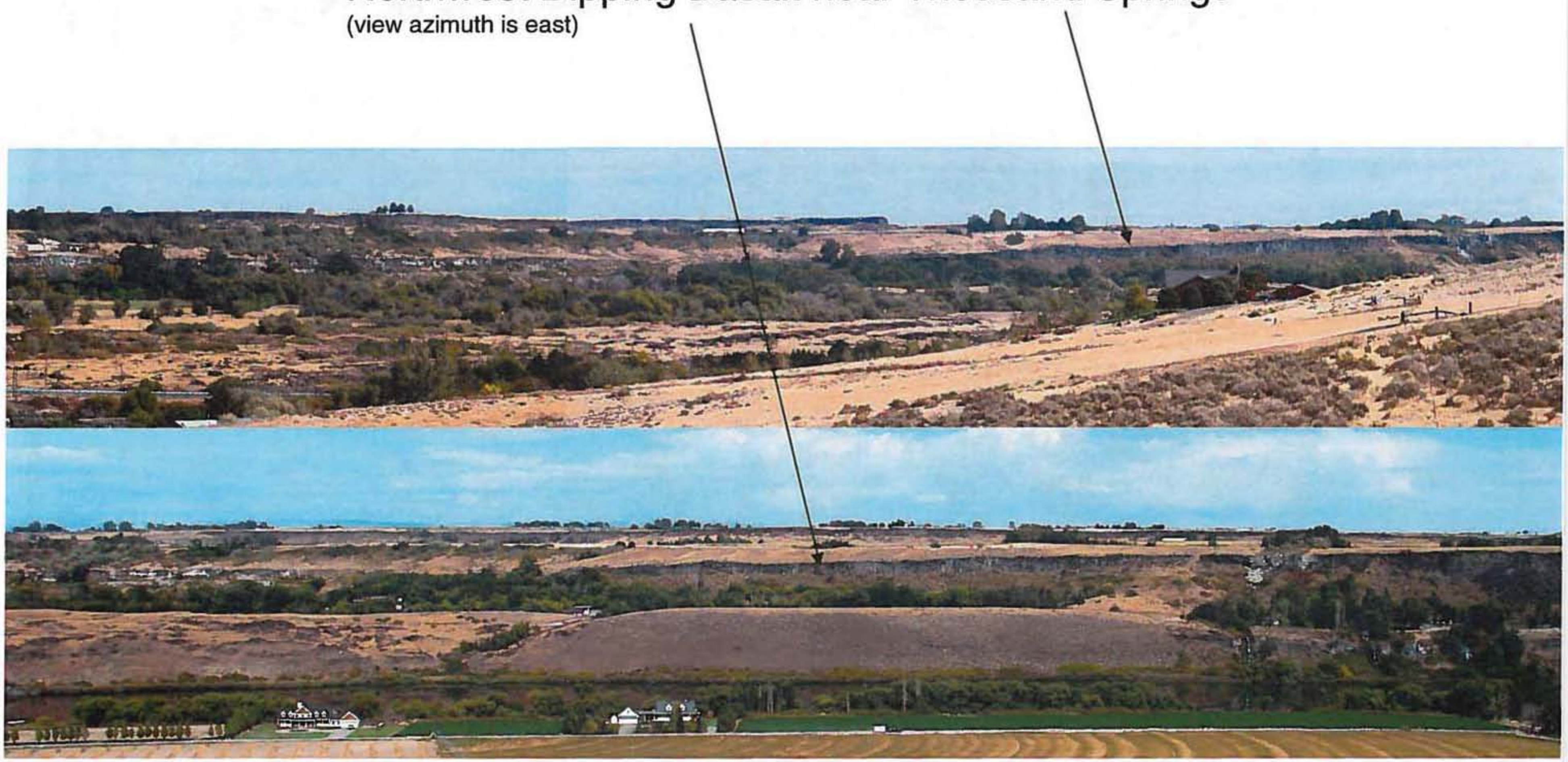
Mass Movement Deposits
Mixed Lacustrian and Alluvial Deposits
Volcanic Deposits
Qlsa
Qf
Qls
Qam
Qaf
Qas
Qoam
Qoas
Qoab
Qams
Bonneville Flood Deposits
14,500 years
Qabg
Qabgl
Qabs
Qcg
Qy
0.052 Ma[1]
Qmk
Qnb
0.373 Ma[1]
Qgb
0.404 Ma[1]
Qma
Tt
3.40 Ma[1]
Tsh
Tshv
Tsgf
3.79 Ma[2]
4.18-4.29 Ma[3]
4.4 Ma[4]
4.46 Ma[5]
Tos
Tub
Teh
HOLOCENE
PLEISTOCENE
PLIOCENE
PLIOCENE OR MIOCENE
QUATERNARY
TERTIARY
rage plateau age, Tauxe and others (2004).
rage plateau age, Hart and Brueseke (1999).
art and Brueseke (1999).
strong and others (1975).
, Esser (2005).
Lacustrian, Alluvial, and Flood Deposits
Volcanic Units
Qam
Qaf
Qas
Qoam
Qams
Bonneville Flood Deposits
14,500 years
Qabg
Qabgl
Qabs
Qcg
Qy
0.052 Ma[1]
Qmk
Qnb
Qbby
Qbbo
0.33 Ma[2]
Qftb
0.395 Ma[1]
Qgb
0.373 Ma[1]
0.404 Ma[1]
Qma
Tt
3.40 Ma[3]
3.79 Ma[3]
Tsgf
4.18-4.29 Ma[4]
4.4 Ma[5]
4.46 Ma[2]
Tos
Tub
rs (2004).
ke (1999).
HOLOCENE
PLEISTOCENE
PLIOCENE
PLIOCENE OR MIOCENE
QUATERNARY
TERTIARY

Northwest Dipping Basalt on west side of Snake River

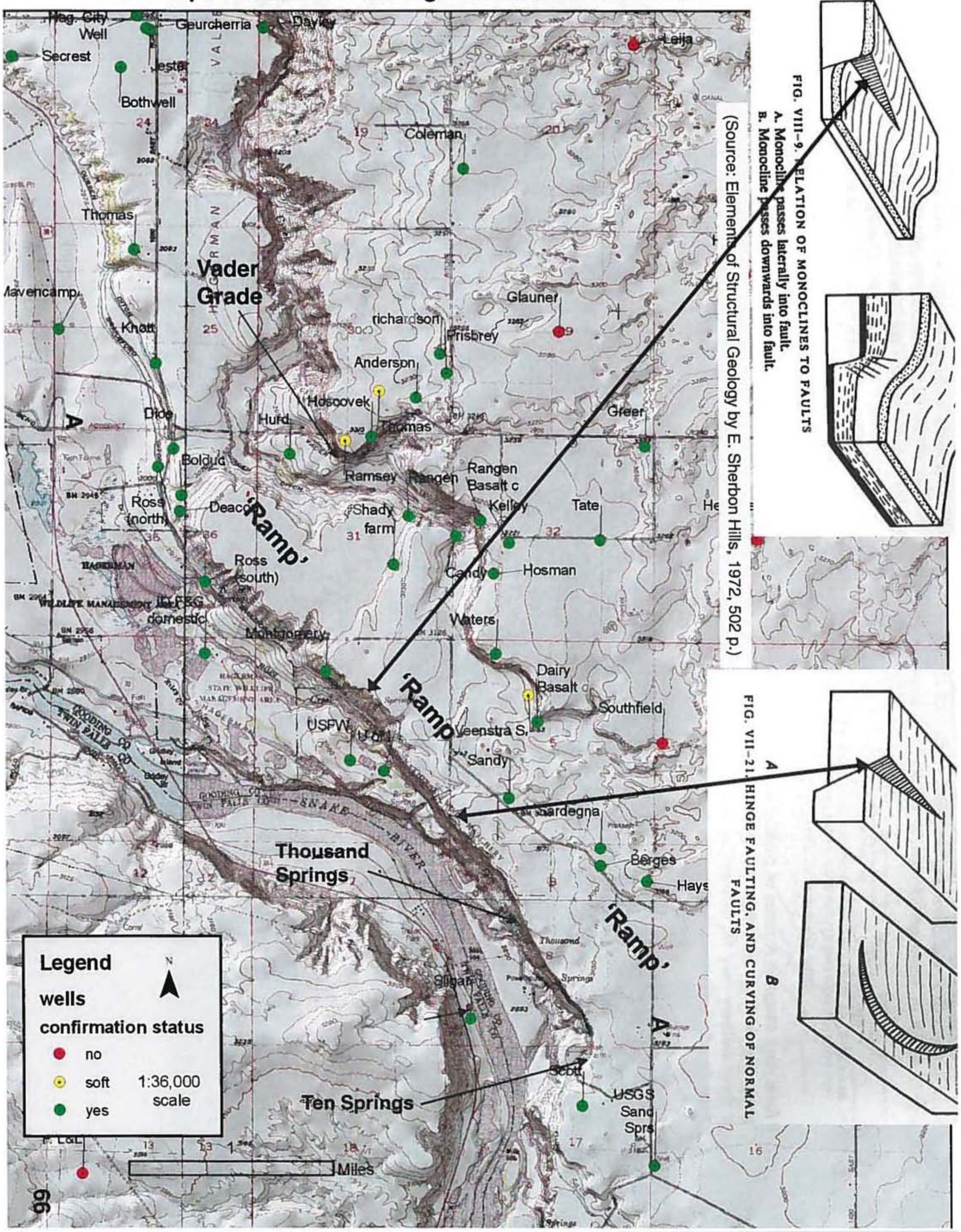
(view azimuth is to the west from National Fish Hatchery)

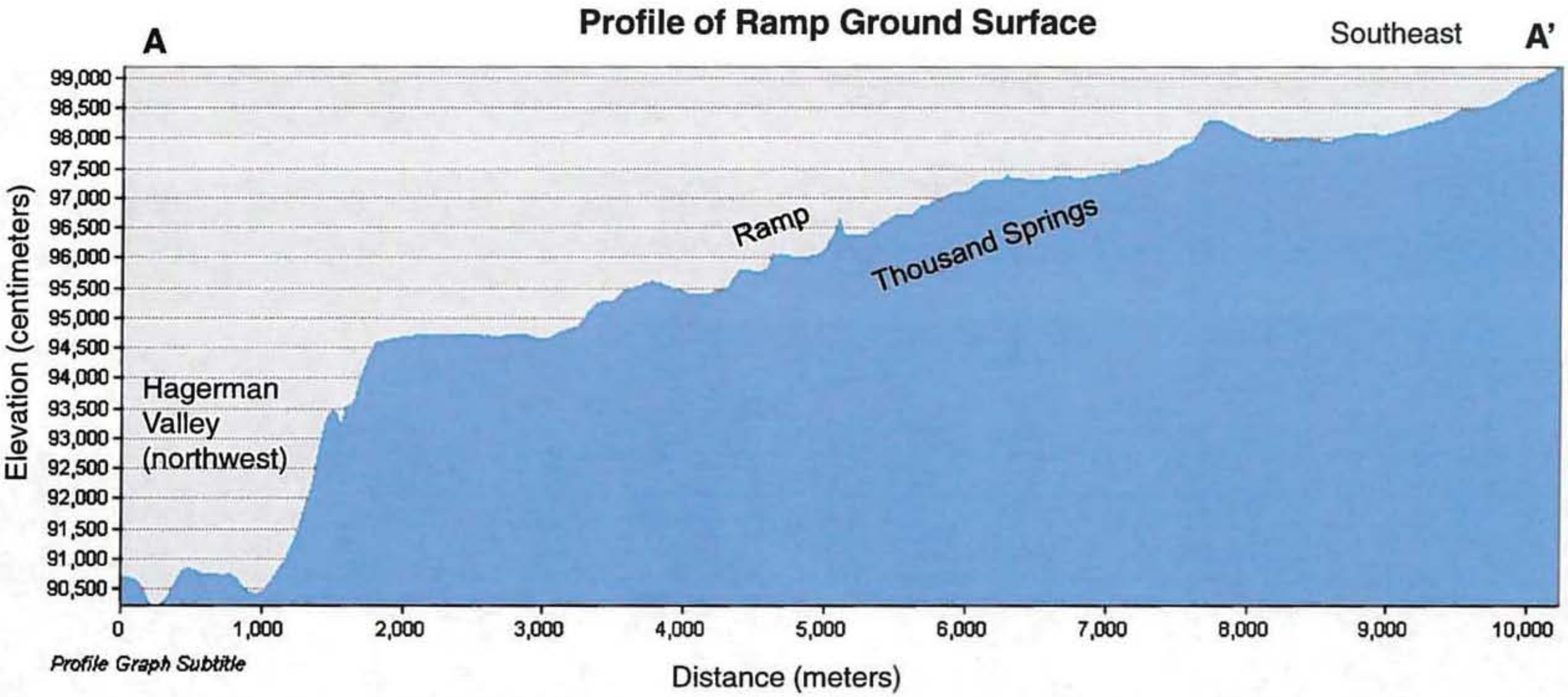
Northwest Dipping Basalt near Thousand Springs

(view azimuth is east)

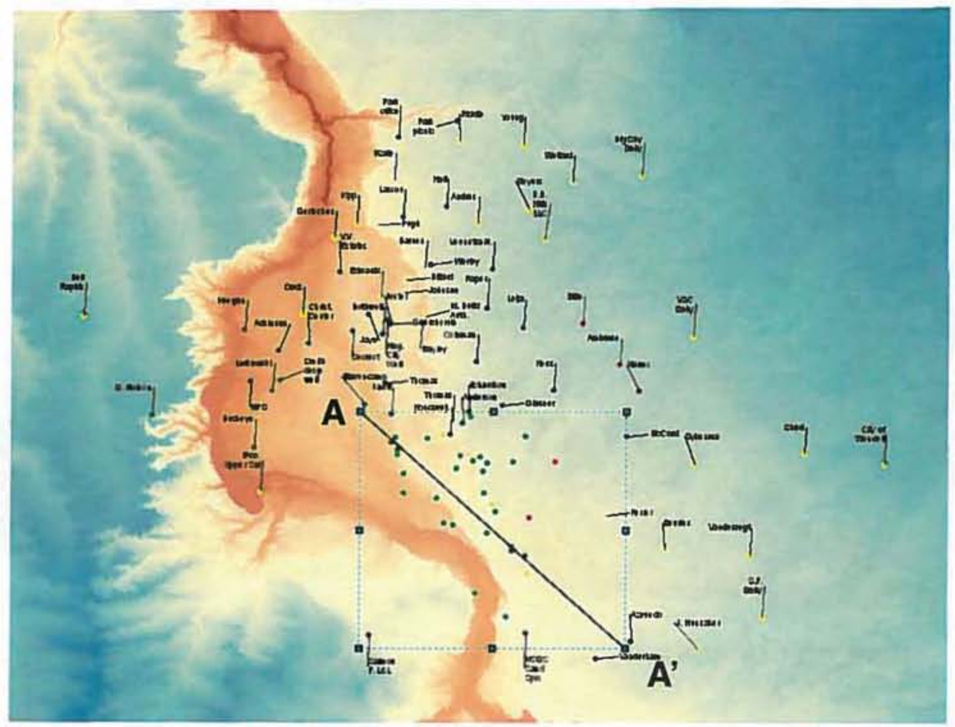


Conceptual Model for Geologic Structural Architecture





Profile of Ramp Ground Surface
A
Southeast
A'
99,000
98,500
98,000
97,500
97,000
96,500
96,000
95,500
95,000
94,500
94,000
93,500
93,000
92,500
92,000
91,500
91,000
90,500
Elevation (centimeters)
Hagerman Valley (northwest)
Ramp
Thousand Springs
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Profile Graph Subtitle
Distance (meters)

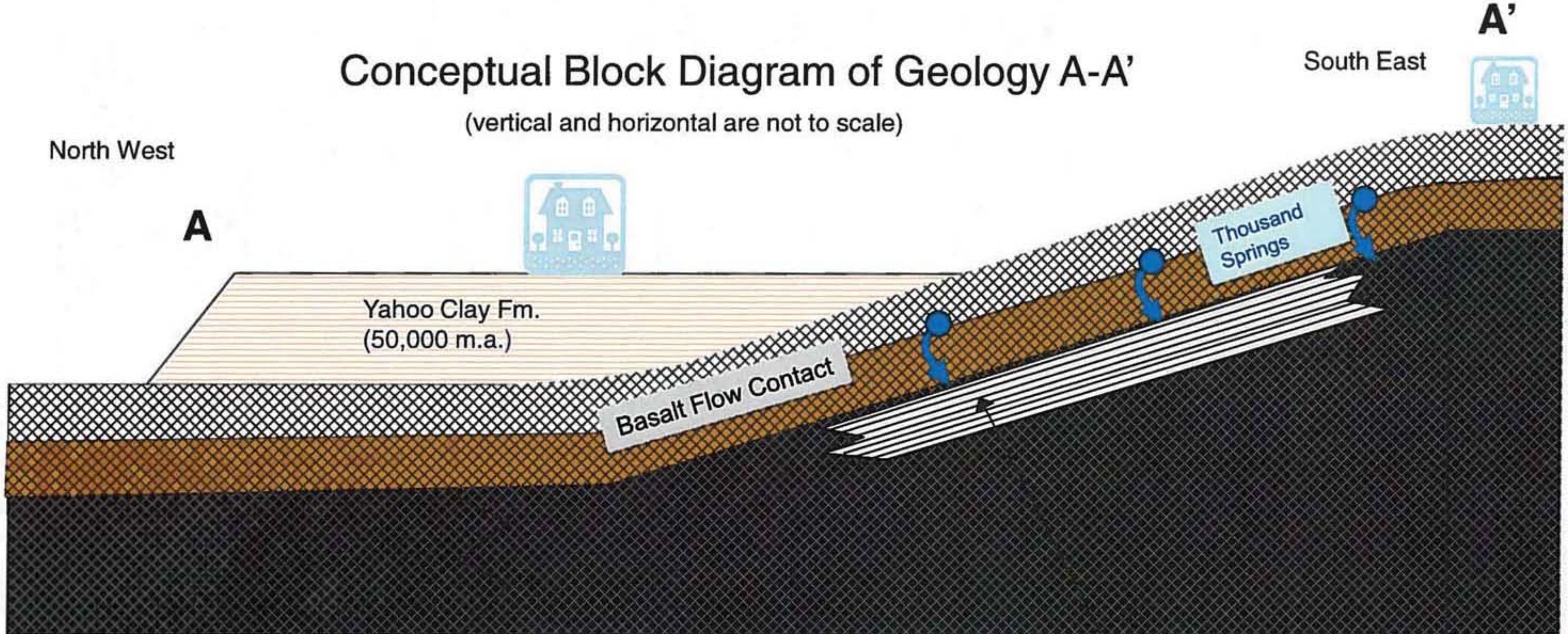


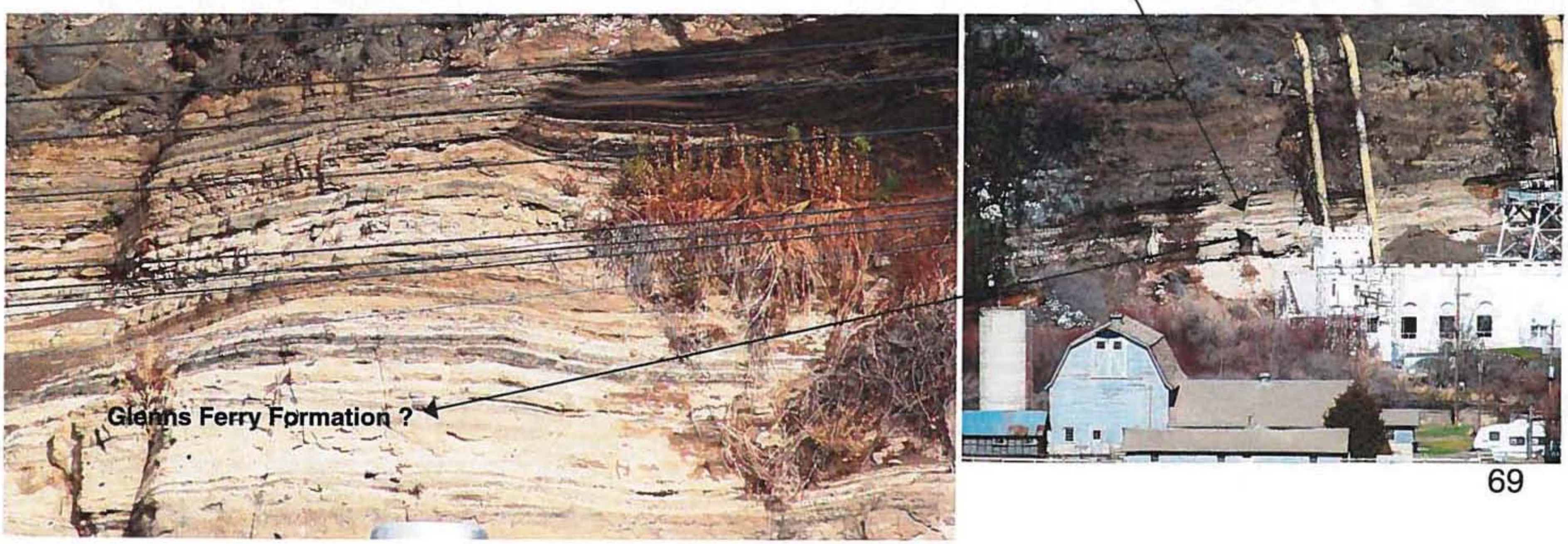
A
A'

Thousand Springs – note the dip of the springs and contact.

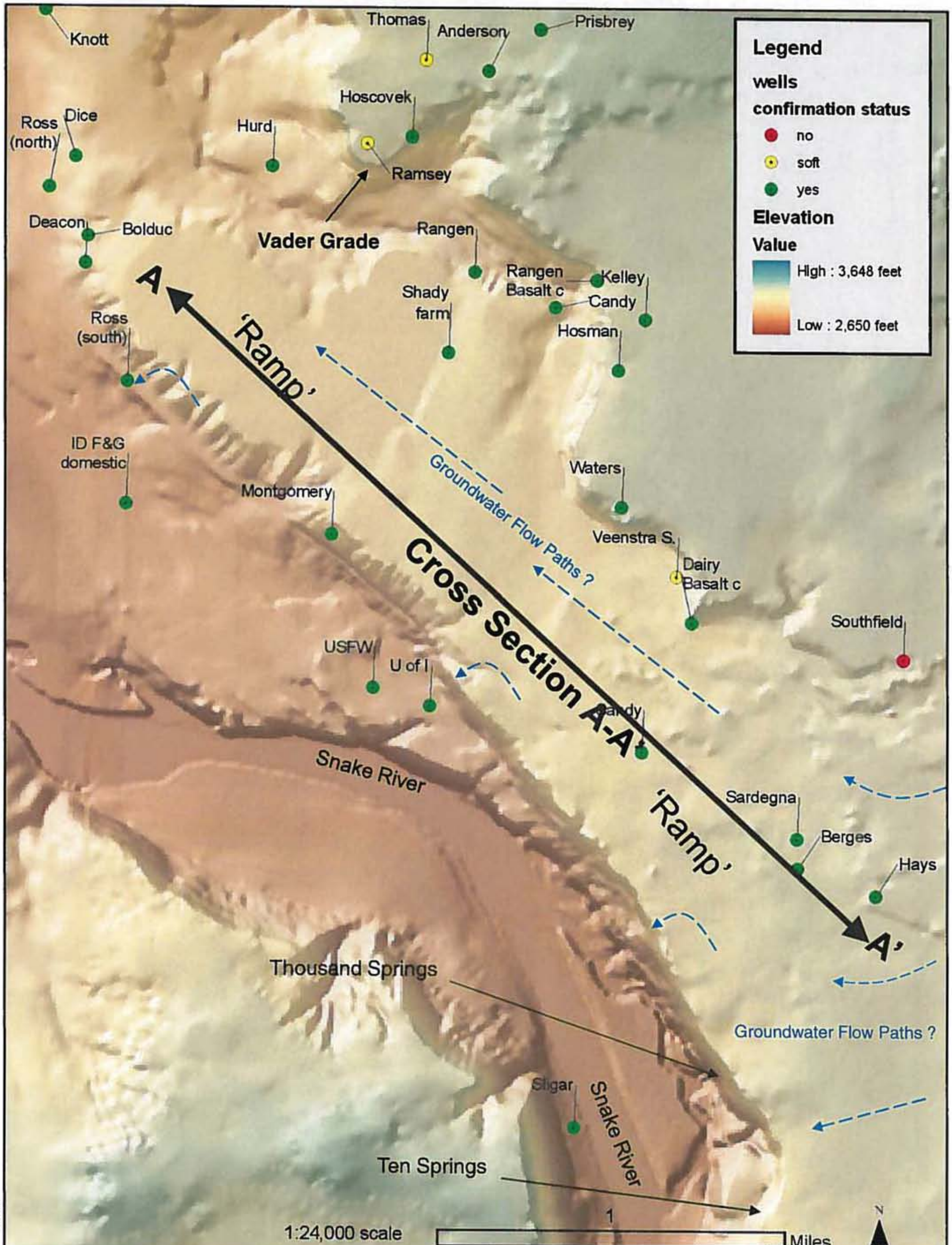
Conceptual Block Diagram of Geology A-A'

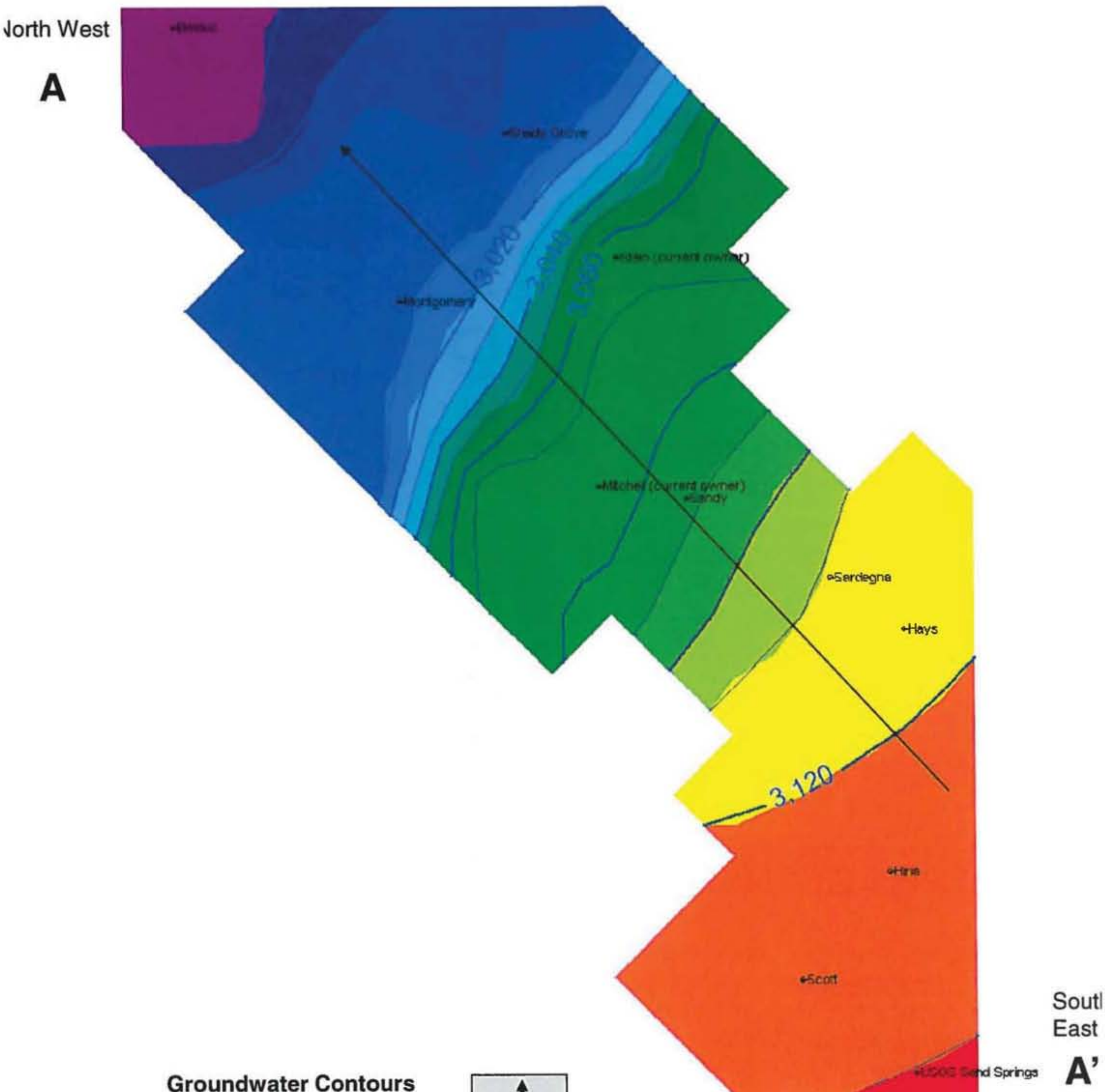
(vertical and horizontal are not to scale)





'Ramp' Area Wells





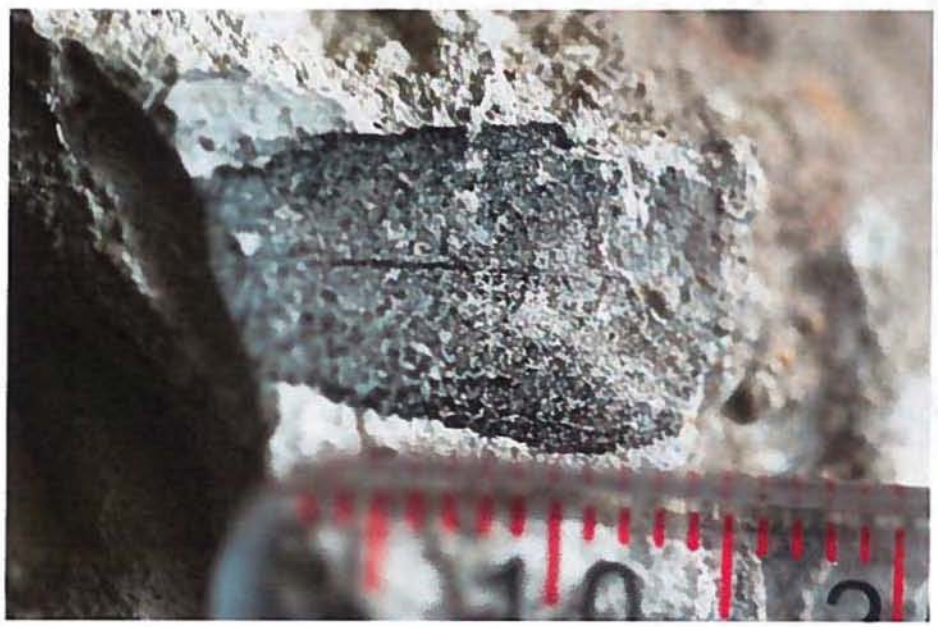
Groundwater Contours down 'Ramp' Structure with flow line.

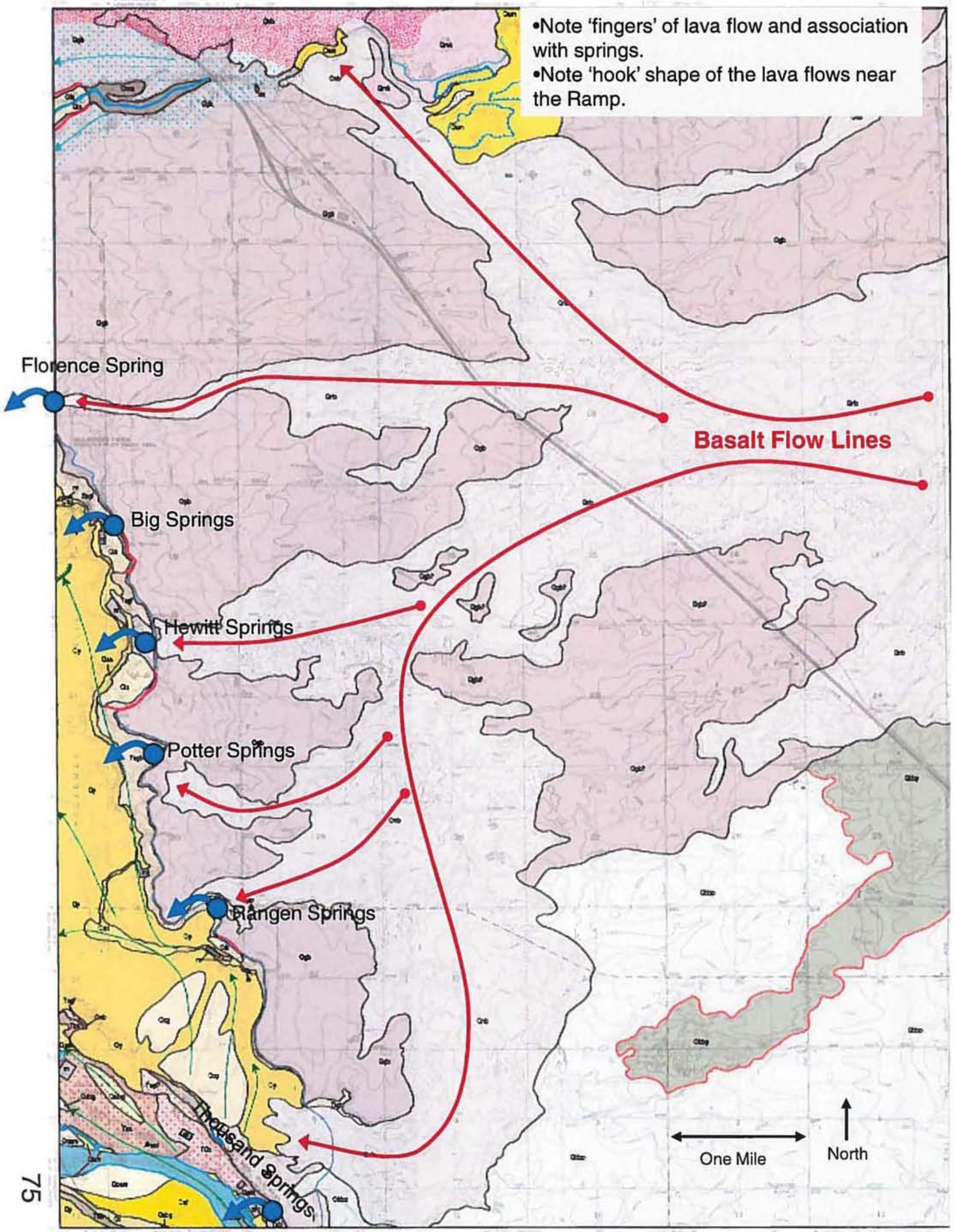
North

Vader Grade Road Cut Stop

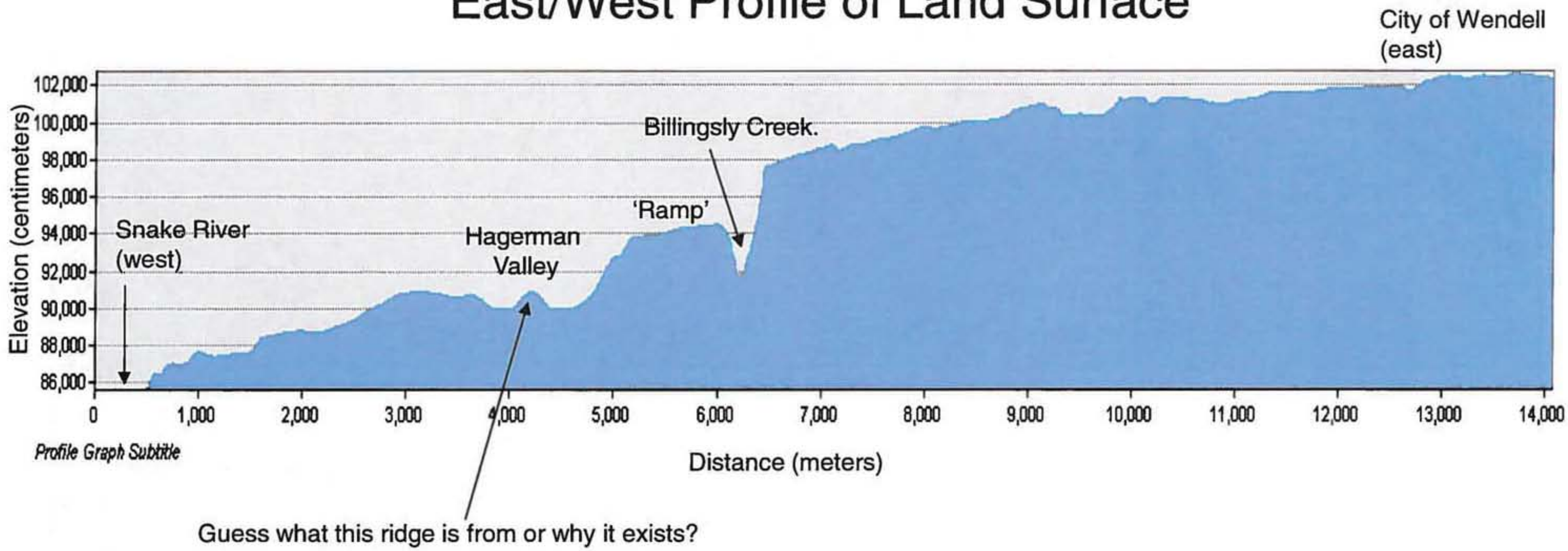
Vader Grade GFF Fossils

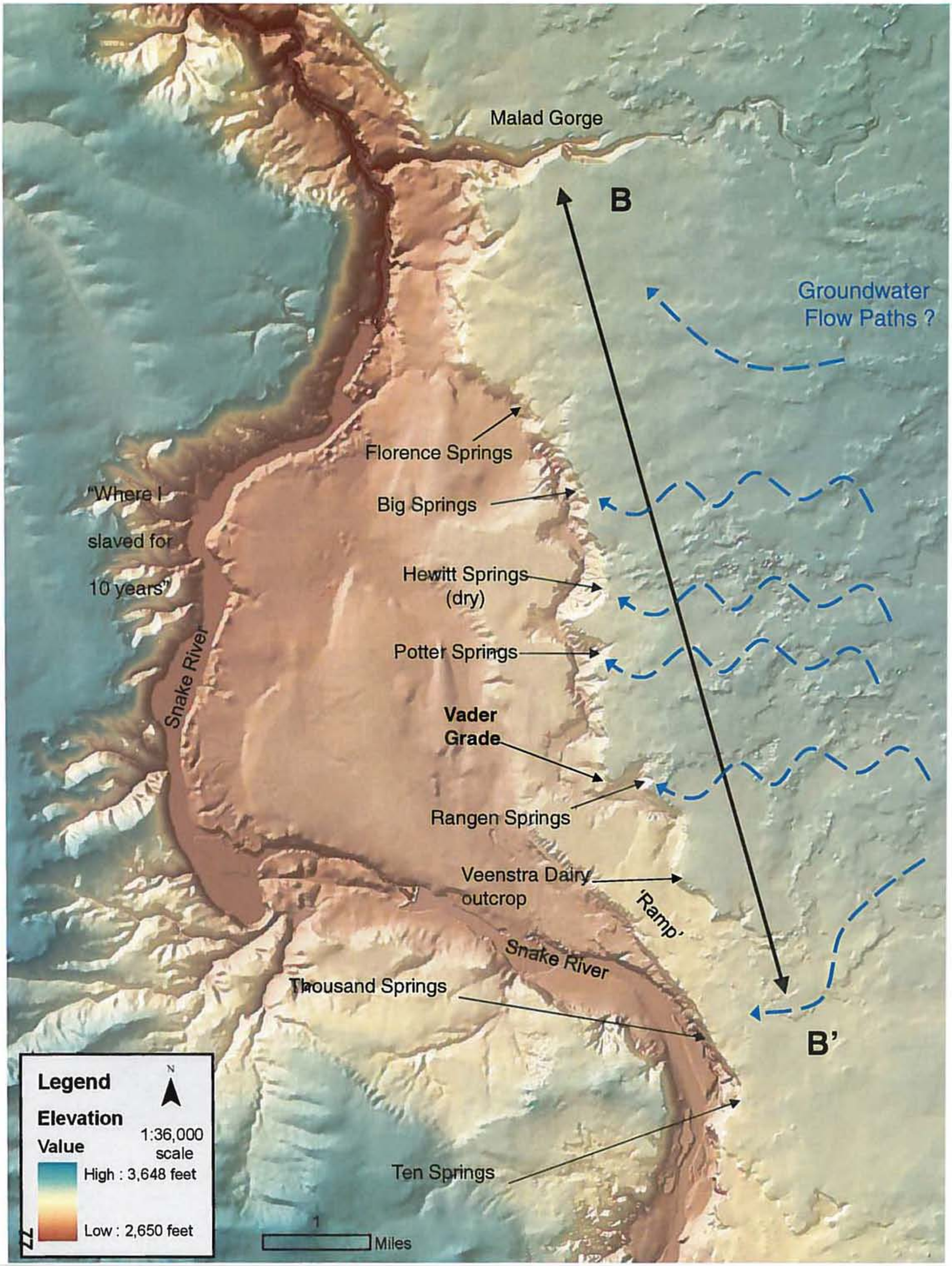
Vader Grade GFF Fossils

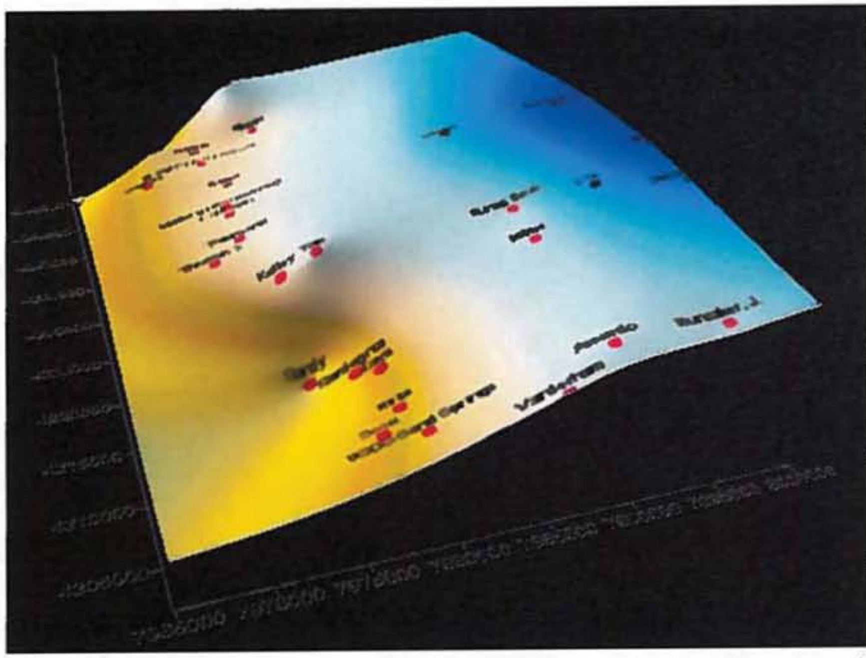


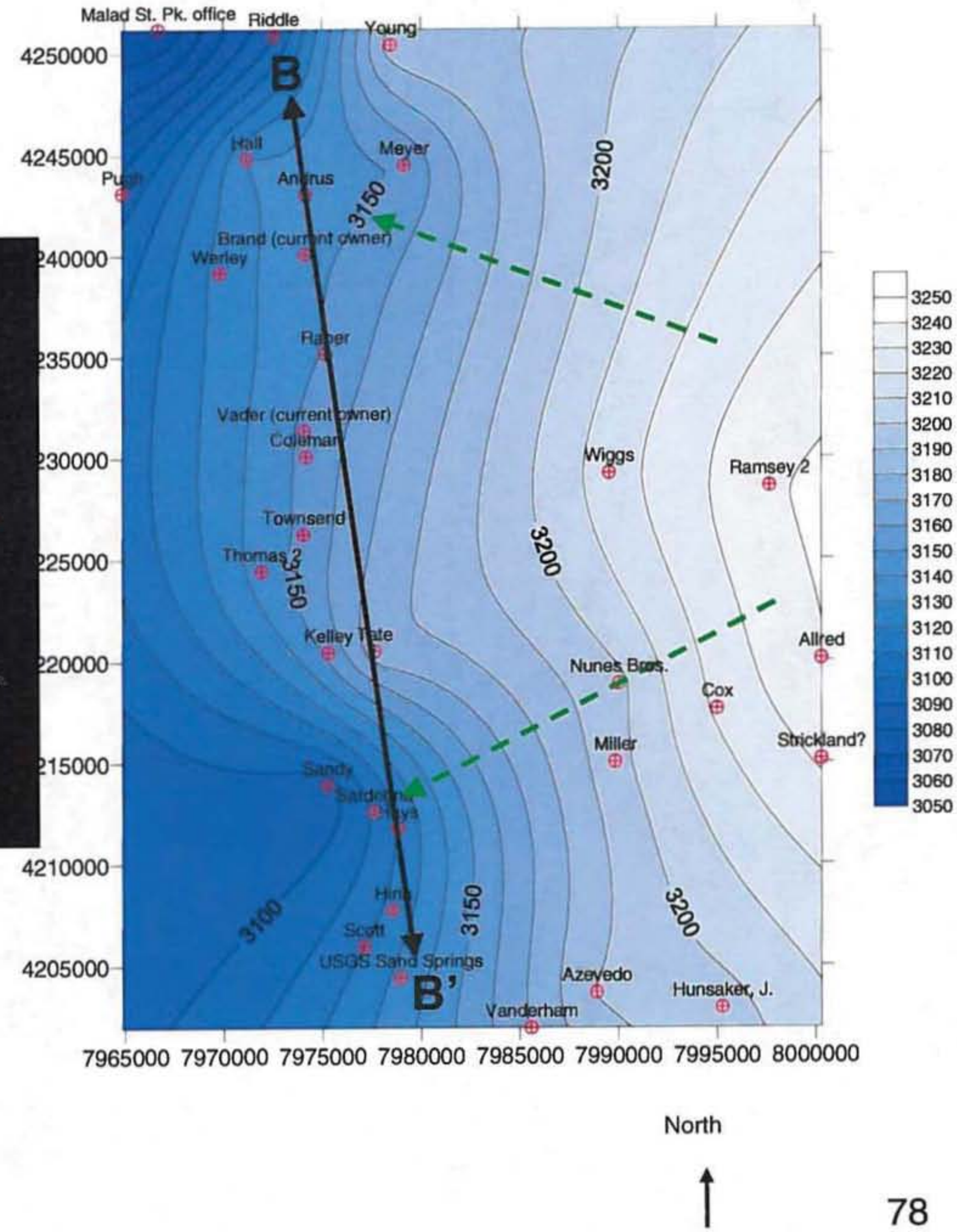

•Note 'fingers' of lava flow and association with springs.
•Note 'hook' shape of the lava flows near the Ramp.
Florence Spring
Basalt Flow Lines
Big Springs
Hewitt Springs
Potter Springs
Rangen Springs
Thousand Springs
One Mile
North

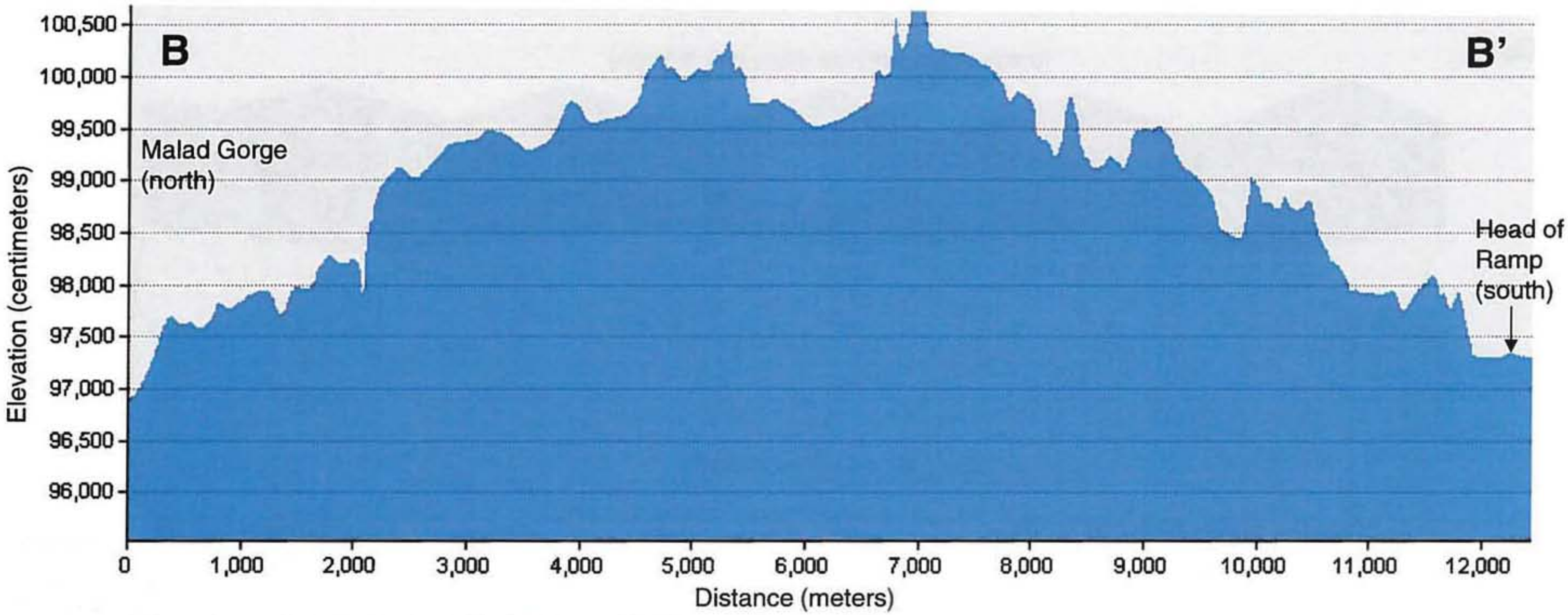
East/West Profile of Land Surface

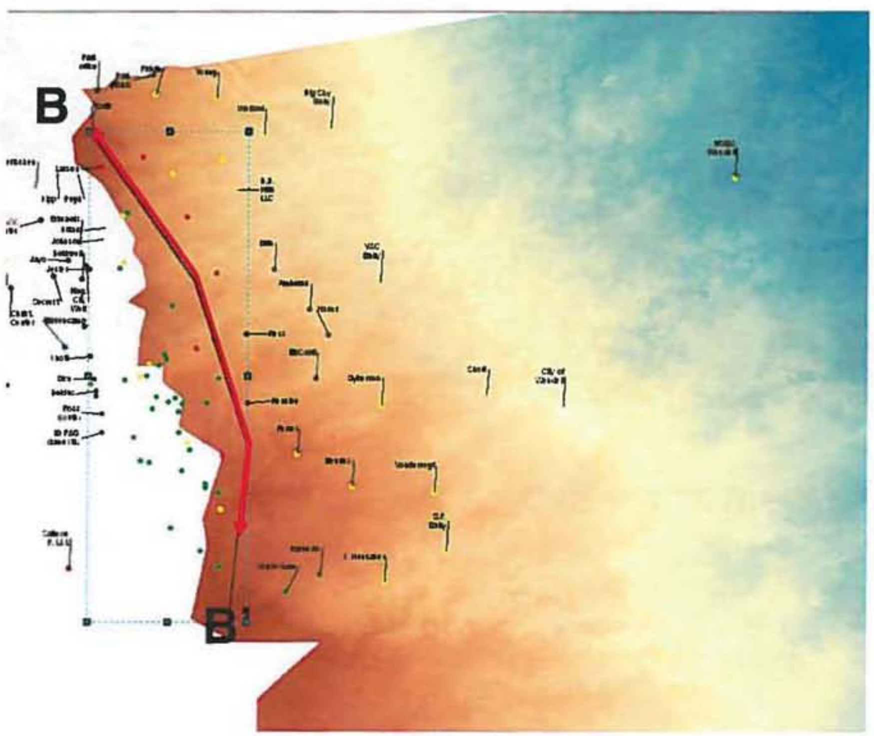



Malad Gorge
B
Groundwater Flow Paths ?
Florence Springs
"Where I slaved for 10 years"
Big Springs
Hewitt Springs (dry)
Potter Springs
Snake River
Vader Grade
Rangen Springs
Veenstra Dairy outcrop
'Ramp'
Snake River
Thousand Springs
B'
Ten Springs
Legend
Elevation
Value
High : 3,648 feet
Low : 2,650 feet
N
1:36,000 scale
1
Miles



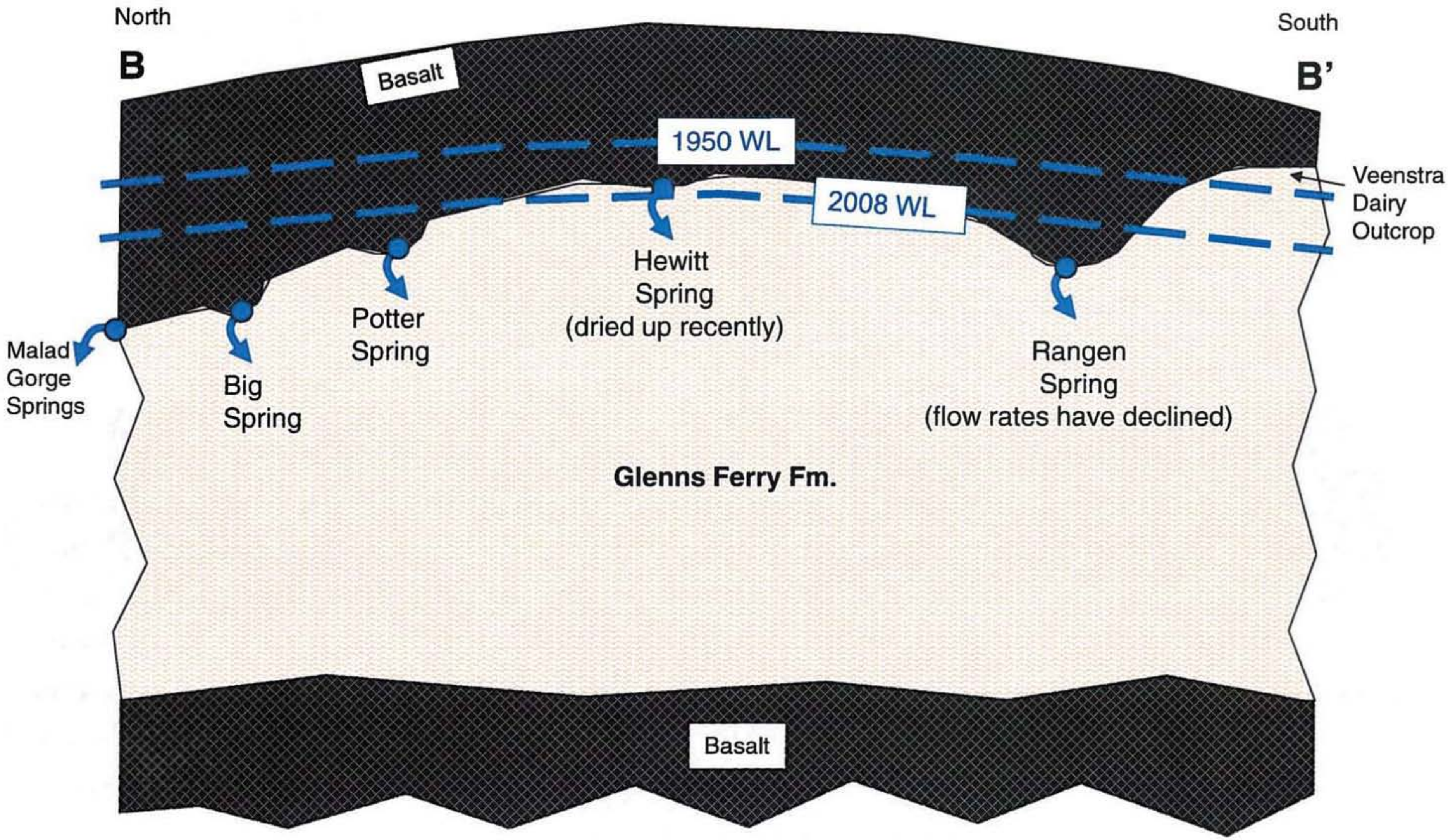

Malad St. Pk. office
Riddle
Young
Pugh
Hall
Andrus
Meyer
Brand (current owner)
Warley
Raper
Vader (current owner)
Coleman
Townsend
Thomas 2
Kelley Tate
Sandy
Saldetha
Haya
Hing
Scott
USGS Sand Springs
Vanderham
Azevedo
Hunsaker, J.
Wiggs
Ramsey 2
Nunes Bros.
Cox
Miller
Allred
Strickland?
B
B'
3100
3150
3200
4205000
4210000
4215000
4220000
4225000
4230000
4235000
4240000
4245000
4250000
7965000 7970000 7975000 7980000 7985000 7990000 7995000 8000000
3250
3240
3230
3220
3210
3200
3190
3180
3170
3160
3150
3140
3130
3120
3110
3100
3090
3080
3070
3060
3050
North





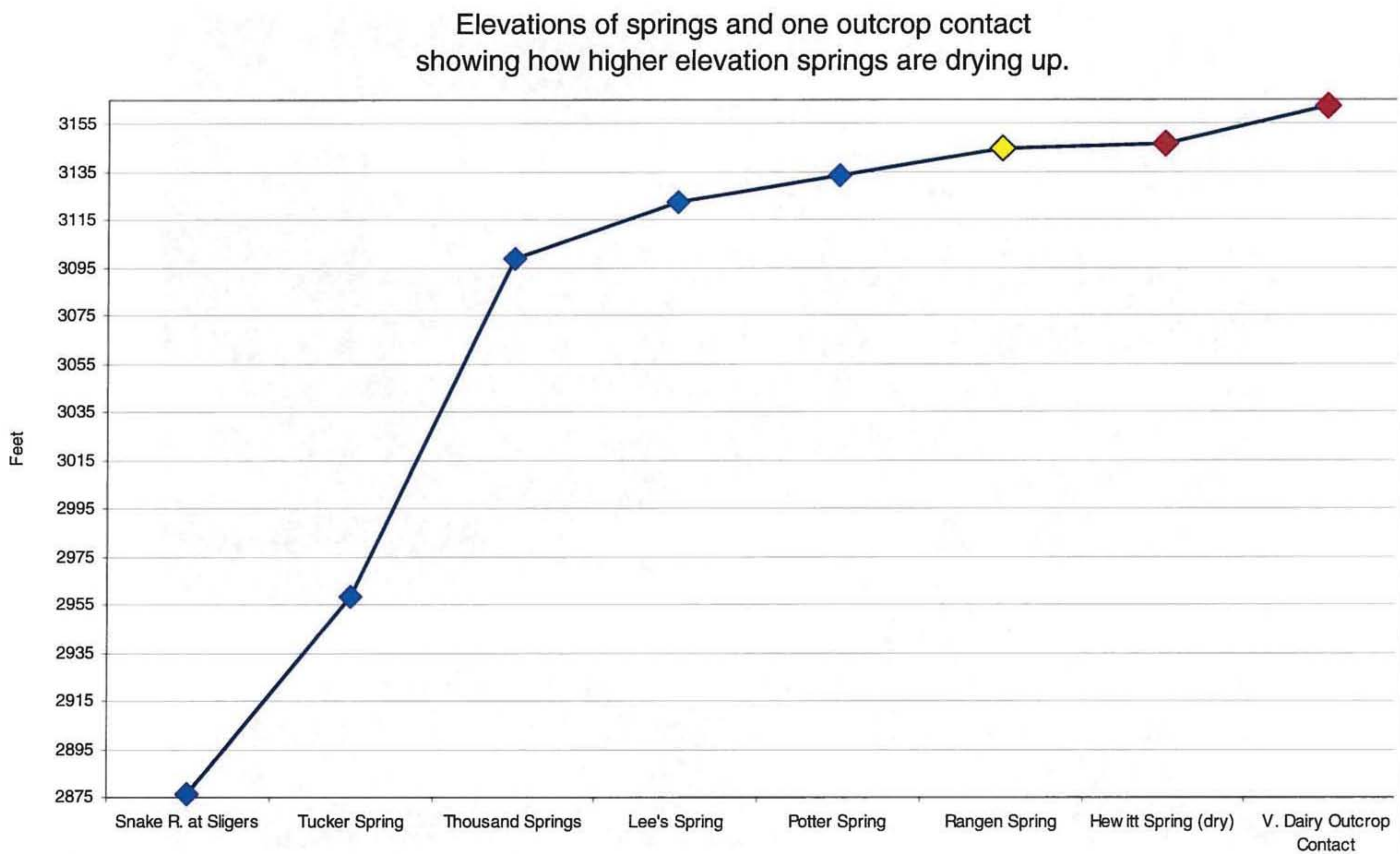
Ground surface profile from Malad Gorge to Thousand Springs area showing a arched feature which correlates to the groundwater contours.

Conceptual Block Diagram



(vertical and horizontal are not to scale)

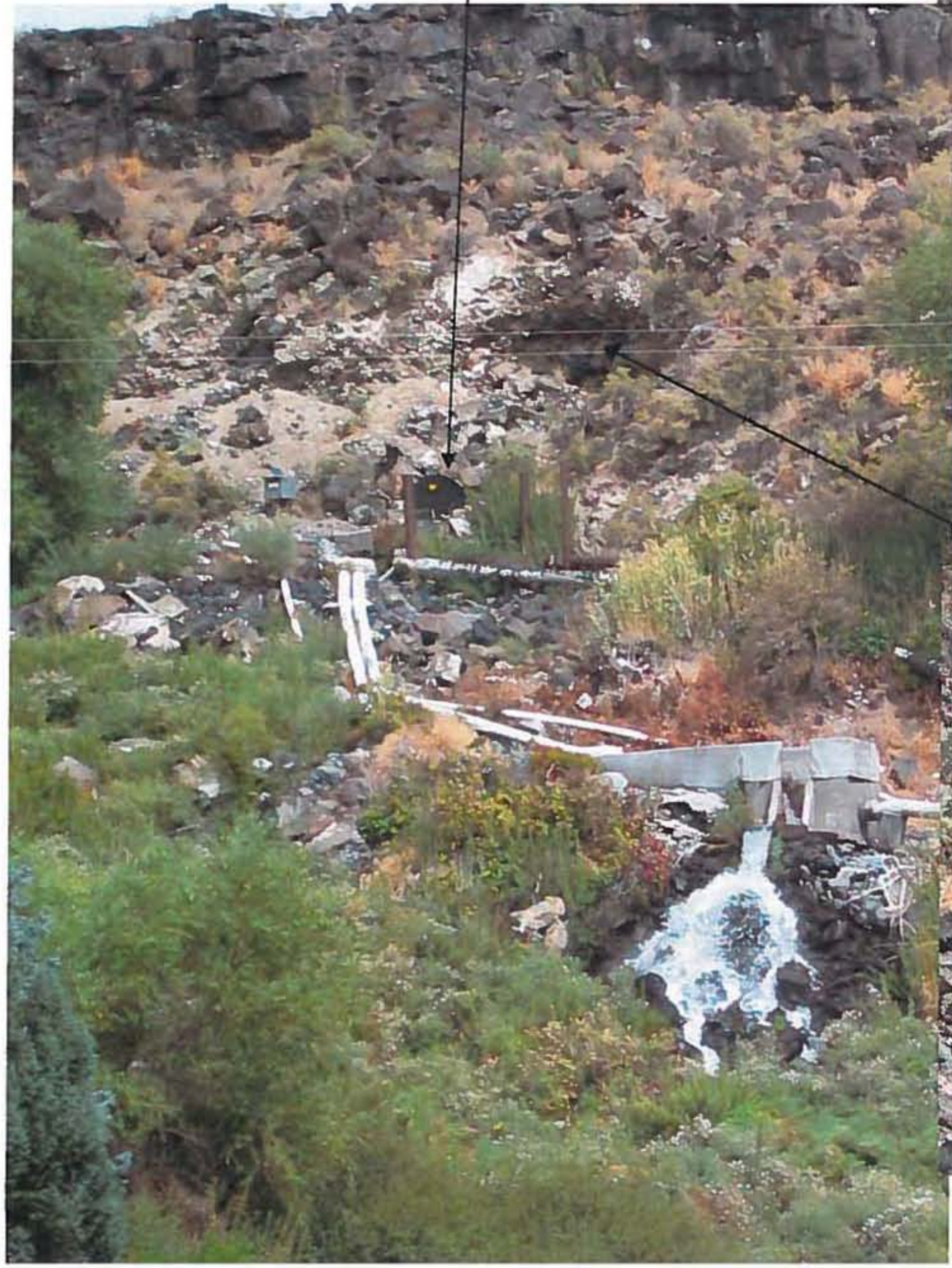
Outcrop example of a paleo-topographic low depression which groundwater may prefer to follow but this is a reverse geology of Rangen site and no groundwater is discharging here.

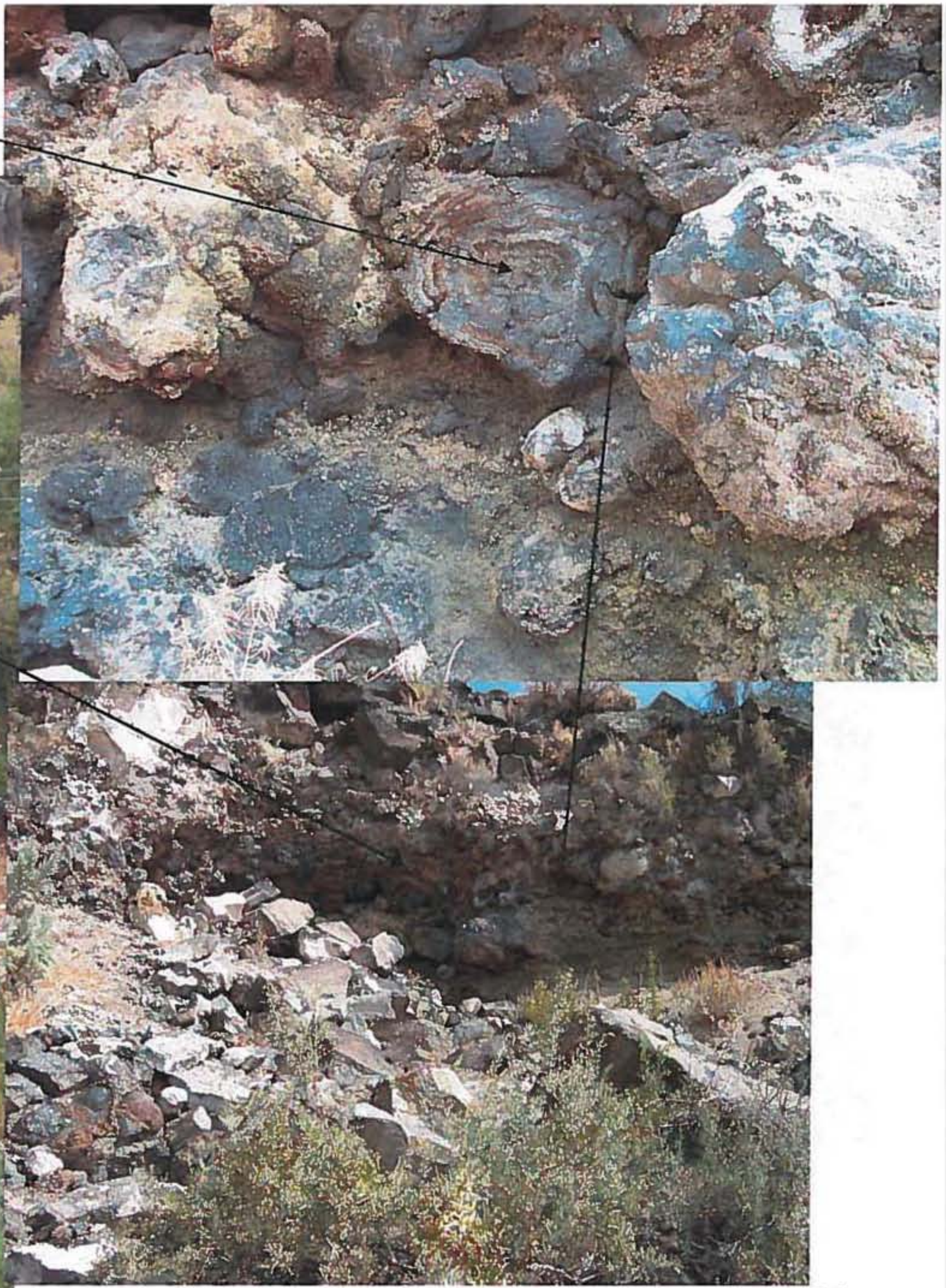

Elevations of springs and one outcrop contact
showing how higher elevation springs are drying up.
Feet
3155
3135
3115
3095
3075
3055
3035
3015
2995
2975
2955
2935
2915
2895
2875
Snake R. at Sligers
Tucker Spring
Thousand Springs
Lee's Spring
Potter Spring
Rangen Spring
Hew itt Spring (dry)
V. Dairy Outcrop Contact

Hewitt Spring (dry)

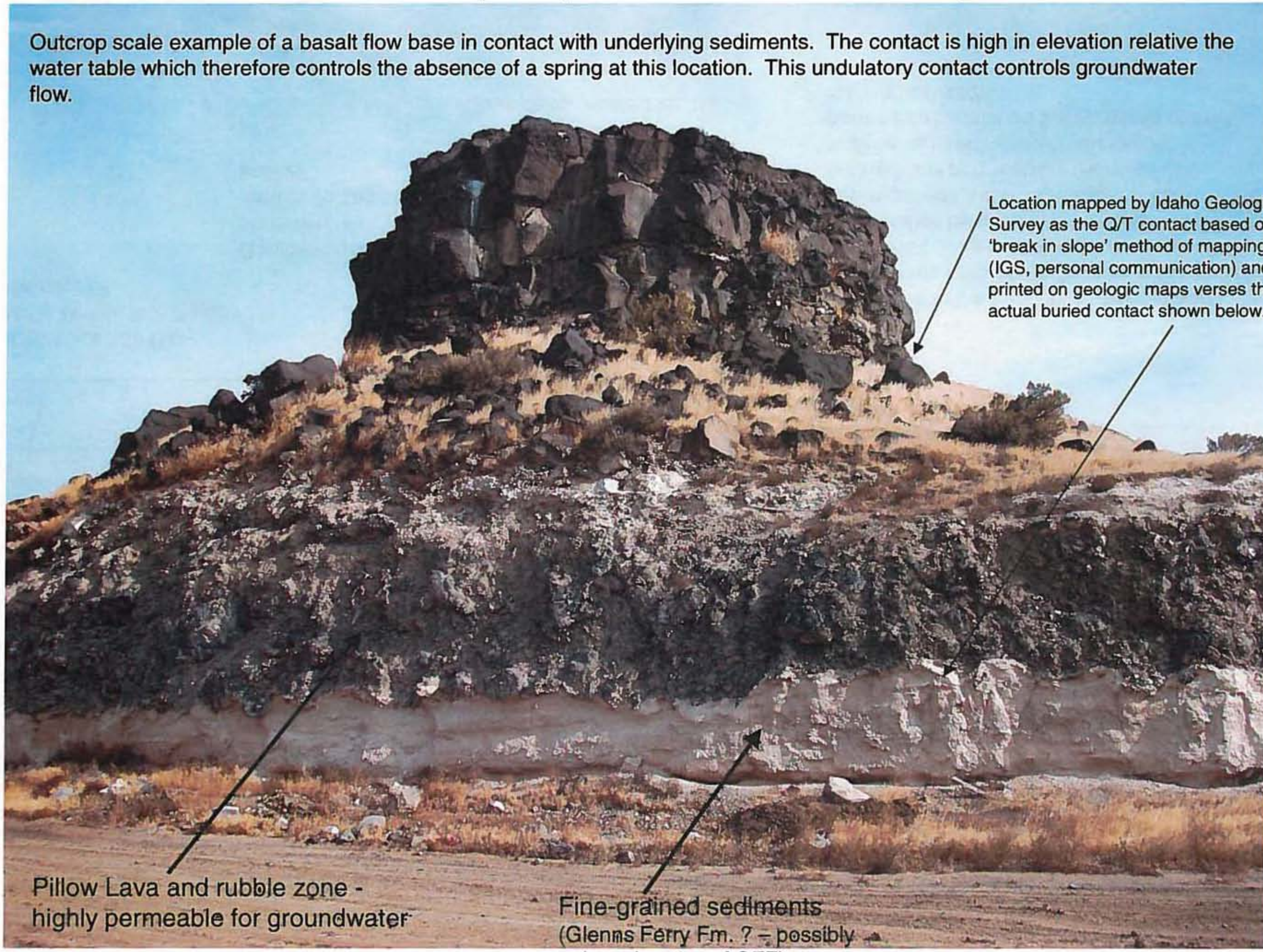
The groundwater table has dropped below the elevation of the spring.

Rangen Spring – compare to Veenstra Dairy Geologic outcrop.



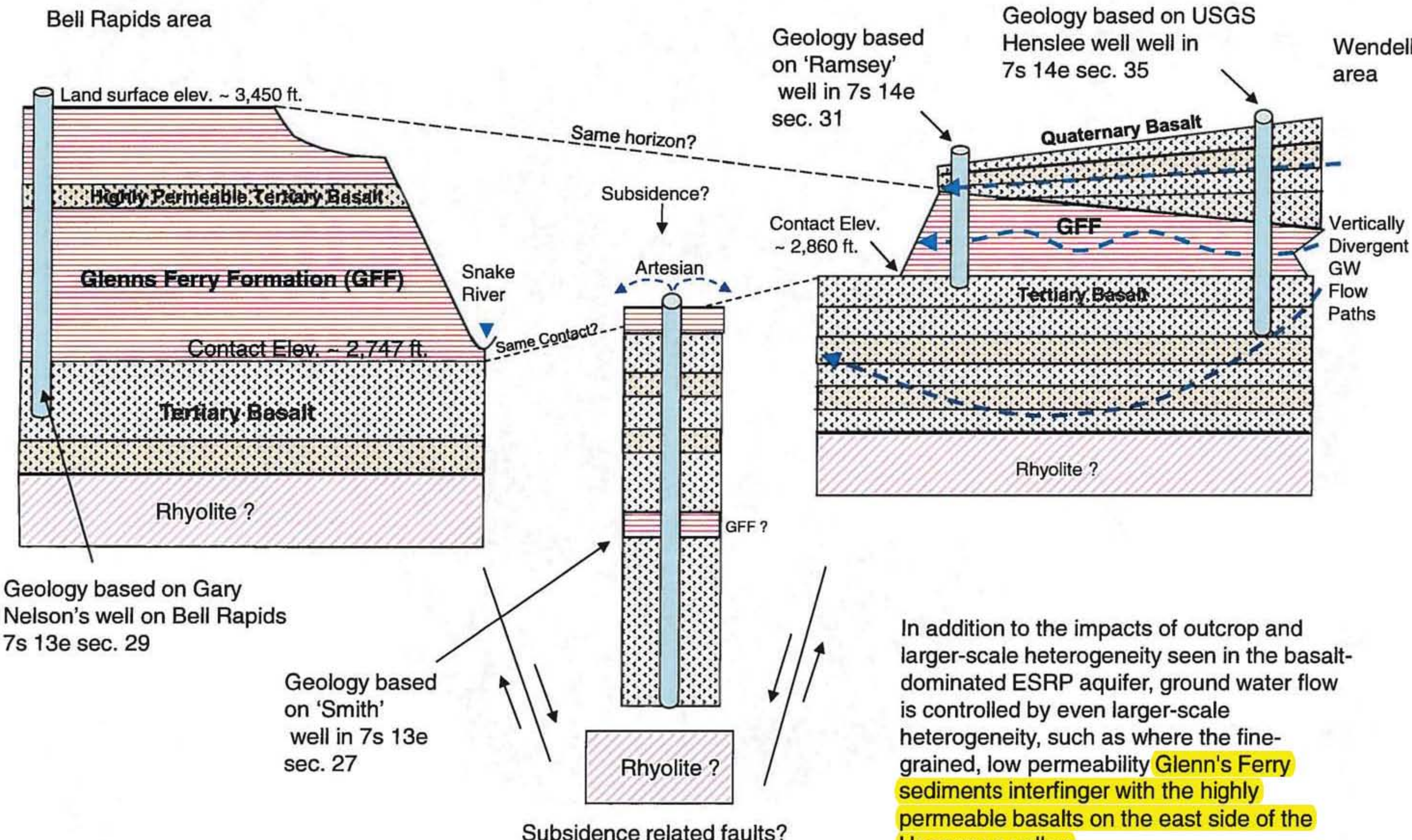


Veenstra Dairy outcrop contact south of Vader Grade outcrop.



"East Meets West" – Geologic Transition Zone of the Eastern and Western Snake River Plain

(Conceptual Model)



In addition to the impacts of outcrop and larger-scale heterogeneity seen in the basalt-dominated ESRP aquifer, ground water flow is controlled by even larger-scale heterogeneity, such as where the fine-grained, low permeability Glenn's Ferry sediments interfinger with the highly permeable basalts on the east side of the Hagerman valley.

Not to scale