GL02562-1

RAFT RIVER GEOSCIENCE SYMPOSIUM

16 Ap 79

532 1055

Rm 145, Colf. Suite: 5 20 p

Nichols - Background & objectives -
- brought out circ 790 graphs of log normal temp distrib of resources -
- could improve efficiency of high temp. conversion and not do too much for economics -- this is not true of mod-temp resources. -
- orig ERDA/USGS objective -- make a complete case study @ Raft River -- apply all techniques -
Objective - "to develop an understanding of fault controlled, lig-dom hydroth systems through work @ RRV

Approach
Method - Review work done (Review Group)
- additional work
- generate single comprehensive physical description
- identify other systems where study is applic. —

- Survey of history -
1975 - first wells drilled - sites recom by USGS
- first well - came in as predicted by USGS, temp, flow rate, depth, etc.
1976 - second well drilled - little higher temp, little lower productivity -
well #3 - stepout to SE - colorful history

- well #3 – a dry well – drilled another leg, then another, got production
- up to this point, all still looked fine – few critics in Washington –
- well #4 – few problems – dropped pipe into hole, screwed up drilling from then on – was drilled into "prod system" – neither of 2 legs encountered production
- well #5 – drilled to west, toward "warmer structure" high flow rate, NaCl used to kill the well – had lots problems – temp is little lower, flow rate OK
- wells 6 & 7 – drilled as injection, near well #3. – Injectability only fair
– in a nutshell – production is only marginal for meeting plant requirements, and reinjection wells are short of being able to take the production

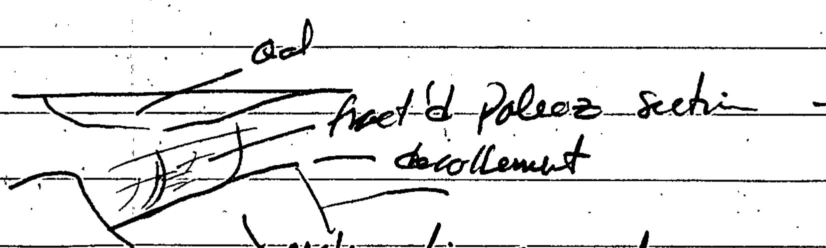
– what DOE wants – our expert opinion re where we should go with small development – future directions – need to confirm resource, then lots of ASDC – level support.

- time schedule
  a) 5 wave construction schedule requires completion of testing in early 1981. – working backwards, drill well in late 1979 is almost too late.
  b) It all looks like stimulation this summer will be needed –

Paul Williams – USGS – Surface Geology

he first started in Aug 1973 – to 1975 – his talk based on view of geol as per 1975 –

Davis & Coney – locations of metamorphic core complexes of N W cordillera – shows such a complex in the RR range – They are characteristic of areas of high heat flow and extensional tectonics. ––



– areas characterized by fractured sed sections above and around core complexes –

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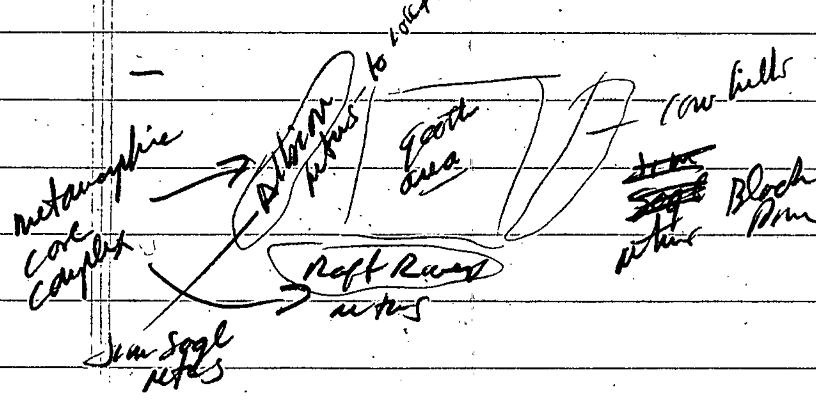


Section

welded tuff = 7 my

Salt Lake Fm

9.2 my

~~[illegible]~~ metamorphosed

upper Paleoz

= Manning Canyon Sh

- Lower Paleoz

PCe

metamorphosed

youngest known volc activity 7 my in welded tuff —

hydrothermal alteration -- weak mineralization

Structure

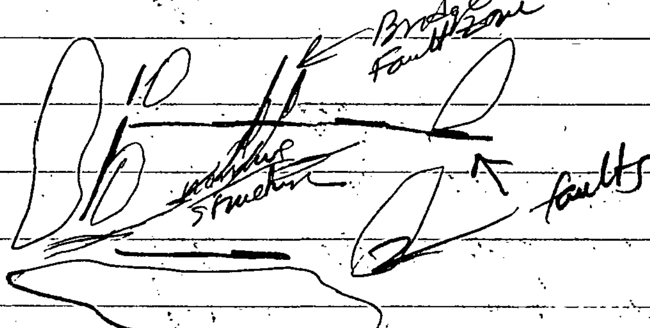
whole area broken by faults —

E-W, NS (B&R) } range front

also NE -- splays to NE -- cuts young Qal

"narrows structure

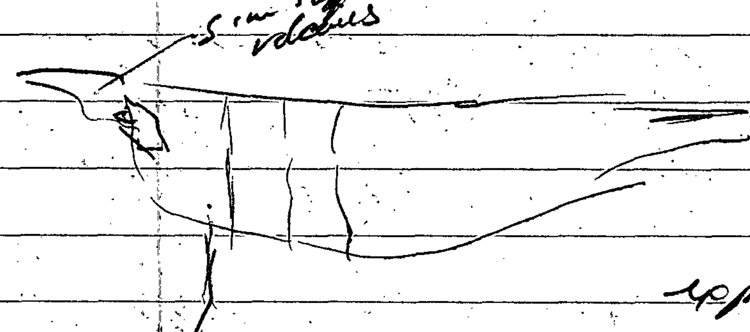
narrows — subsurface known from gp —



Low Sun angle photography - shows faulting in Oal - youngest ≈ 200k years - Horse well Fault (s) -- goes E-W in middle of valley

Jim Sage volcanics -- pretty localized -

-- gothe model @ 1975 -
rainfall in surrounding areas, downward percolation to 5km, heating to 150°C, upwelling in fractured terrain in valley, self sealing w/ silica in spots.



Low ∠ Nnests
exposed in Albion mtns
-- Laramide faults
-- Malay interprets low ∠ glides
@ 11 my, arching and sliding of volcanics out over Oal in Raft River -

Don Mabey – Geophysics
– grouped into 3 parts
1) pre-1973 had done some regional recon
2) intensive gp – coop w/ ERDA – to locate first test well
3) Since then – are as test lab –

– note – have not done work specifically to delineate reservoir after first hole drilled – have considerable data in hand, but no work to define reservoir –

-- have regional grav + mag – pre-1973
mag – 5 mi line spacing
gravity – gravity high on W. side of valley is not our area, but to E of area on Qal – buried ridge in valley dropped off
-- has roughly coincid mag high –

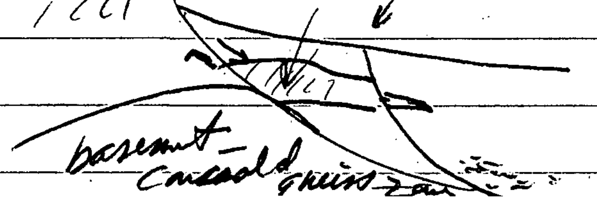
- Curie Point Calculations - Bernd B. - calculated Curie Point
  -- there is a high in the Curie Pt -- to 8 km above sea level -- shallowest in S. Idaho, comparable to Yellowstone -

- Telluric Current Map - relative ρ to considerable depths - low coincides w/ center of valley, w/ low widening over reservoir
  - had 1 MT sounding -- shows 1 Ω-m @ 7 km only sounding in whole area -- agrees w/ Curie Isotherm determination - this type of sequence also seen other places in Idaho - e.g. Yellowstone

- Detailed Gravity -
  did simple "3-D" (?) inversion -- meant 1D -
  Strange positive feature - in gravity

- Detailed A/M - large (+) mag high sits to E of gravity high
  -- no evidence of volcanics in valley fill ~~[illegible]~~ rhyolite pinches out from W to E -

E-W Profile [illegible] Reservoir



Faulted-off portion of Jim Sage volcs cause mag high -

- AMT - 26 Hz - nice ρ low defined in al area reservoir - does not penetrate to reservoir depths, but shows commonly a ρ low which overlies reservoirs due to alteration, etc -

DC Resistivity - Zohdy - bi-di map -
shows highs & lows

has been able to map top of basement w/ soundings - no strong anomaly @ depth corresponds to reservoir -- p'ly due to good water quality in reservoir -

Refraction Seismic - Hans Ackermann
- got good data
- Don put section together
- was able to map top of Pre-Tert basement
- got ~~poor~~ transverse anomalies in Tert --
  prob voles, etc. -- in vicinity of
  Narrows structure, Bridge fault zone
- got velocity anomalies in basement itself low velocity

SP Survey — got anomalies aligned w/ faults
-- some anomalies explanation unknown -

Thermal IR — mapped hot areas on thermal IR
due to hot water along faults

Controlled Source EM — Hasn't added much -- just
tests of techniques -

Conclusions - regional picture fairly complete -
would be nice to have more detailed data in
vicinity of reservoir -- to see if we could
map fractures -- main item reflection seismic
needed -- prob offers best promise of getting detail
of structure -

all of data are avail on open file -
Recent public in Geophysics
Zohdy preparing paper on ρ
Achmann - refraction in Geoph
all out

Harry Covington – Subsurface Geology –

– Since 1974, 85 wells drilled in RR valley

35 auger holes ~~USGS~~

1 Bridge offset well

6 inter depth core

2 inter depth rotary – upper valley

24 heat flow

USGS

7 monitor wells EG&G

5 heat flow EG&G

7 geothermal ERDA

3 wells by Std Annie Petroleum – pet tests –

35 Aug holes in silts & al -- almost all unalt's except in Narrows

1 Bridge -- RRG#1 nearby – silicified

2 ~~6~~ interdepth – same in Test – unaltd –

24 heatflow – 7 & 8 reached silicified seds + magnetite

6 interdepth core – Some alt –

HF + RDC few but from Sage rhyolite

IP(?)

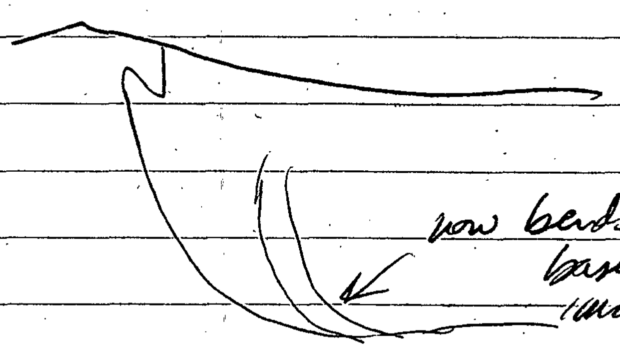
pyrite (?)

all of prod, seq except 6 & 7 drilled into metamorphic basement complex —
— in SLC fm fracts + alt increase w/ depth
— in basement, not much alteration —

Malta, Strawell —

Drilling prog has given decent section of basin —
— 1500 m of fluvial seds derived from surrounding mtn blocks: Paleoz + Pre-C gneisses, core complex —
— rapid lateral & vertical variations — little correlation can be made — 1 gravel zone possibly correlatable —
— contact Qal – Tert is just a guess, too —
downward decrease in gravel, increase in volcanics —
— Ash flow tuffs in Malta & Strawell holes may correlate
— Floor — Pre-C qtzites & schists — correlation can be made between wells — below 150 m qtzites & schists, go into adamellite Pre-C — they look like rocks in ranges around —

— since Sago volcanics seem to wedge out



now bends faults along basement, instead of involving basement.

— Believes "narrows structure" is upward carrier of hot water, which then moves out along Bridge Fault to get into extension fracture system. Cap rocks of silica form when water goes up, interacts w/ upper, cool waters. Si caps best developed in fract'd areas

-- Feels its not possible to tell where to drill w/out drilling [illegible] --

-- evidence of faulting trending parallel to basement
-- drilled into basement looking for Bridge fault, should have hit, but did not

-- little py in wells, little scatt in seds except interval 5A near Sluy [illegible] -- near bottom hit massive sulfides --
-- concentration on fracts & in [illegible] zones --

-- vague about [illegible] --

— magnetite -- found in HF wells 7 & 8 -- depths > 1000 ft
-- origin? [illegible] detrital --

-- get tuffaceous material all way to bottom -

--

Borehole Geophysics - Scott Keys -

- started early on to work @ Raft -- has done some logging on all wells @ Raft - Paper in June issue of GP -

- has done: qtz, K-feld, plag, clay, zeolite + temp -- they show an alteration zone not shown on logs

--

- tried down-hole γ-ray spec.

- Th/U ratio shows peaks @ fract zones = ov zs

- Th/K ratio not anomalous -

-- did lots cross plotting - sonic velocity vs porosity

- γγ vs sonic, other x-plots

- acoustic borehole televiewer
  1.5 MHz rotates 3 rpm
  - sig reflected off wall of borehole modulates z-axis of scope
  - works in muddy fluid -- needs fluid

RHS - got televiewer logs @ 260°C. --

-- have acoustic caliper logs - time signal out & back -- looks back into fracts - good detail

- temp log, computer derived ST, caliper log -- good correspondence

-- sees silicification, dip fracts, openness, etc -

- has some good pictures of fracts in RRGE-2 others

-- showed hydraulic induced fracts from Piceance basin

-- showed accidently induced fract @ RHS, occurred overpressuring

-- believes accid ind fracts occur @ R oft

-Flow meter logs - impeller flow meter --
has good results from RR-

- from Raft - logged isothermal temp -- at first
believed tool not working -- logged flow meter
400 gal/min @ hole top, 325 gpm, 225 gpm
averaging interval, then @ bottom no detectable flow -
cut off @ 4'/min ⇒ : 1690 = bot casing ⇒ 3020 =
bot of hole -

-- Scott showed a fence diagram showing production
zones (water-entries) in wells. --
believes this needs to be updated

-- has ABHB data analysis that shows strike, dip,
hole deviation, etc. -- none of results are
corrected for deviation.

-- have experimented w/ acoustic detection of lithology
differences -

-- oriented w/ magnet

-- have seen ports 1/32" in calib tests.

-- have lots of commercial logs @ Raft. These are
usually poor -- well #6 logged - useless because
caliper off scale -- porosity log too low

They did a std computer interpretation -- garbage in, garbage out. —

Manny Nathenson - Temp. Gradient

TD 5-A - 63°/km upper part; 45 °C/km lower part
— these are sort of typical gradients in this area
take 50°C/km —

Stovell - 50°C/km first 700' -

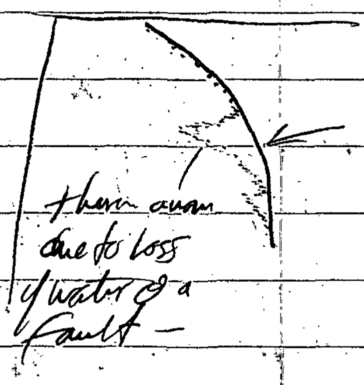
So this looks like the regional gradient -

— in reservoir area: often get gradient reversals; max temp 78°C @ shallow depth — lots of shallow ~~[illegible]~~ movement of hot water

TD 1, -2, -3 were all high gradient holes
-- get 75-150 °C/km -- this could be due to conductive HF 1.5 km deep reservoir

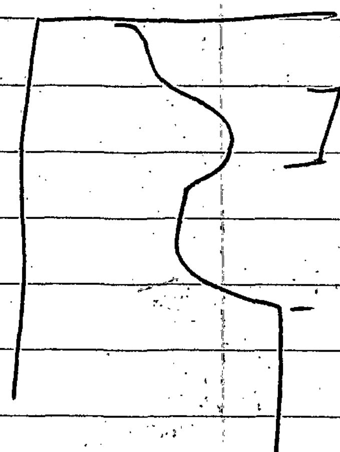
— Almo #1 — 70°C + @ 400' — very anomalous, but gradient plunges way down

RRGE-1 — 10-11°C mean annual
— leg projects to 20°C, so not in equilibrium —



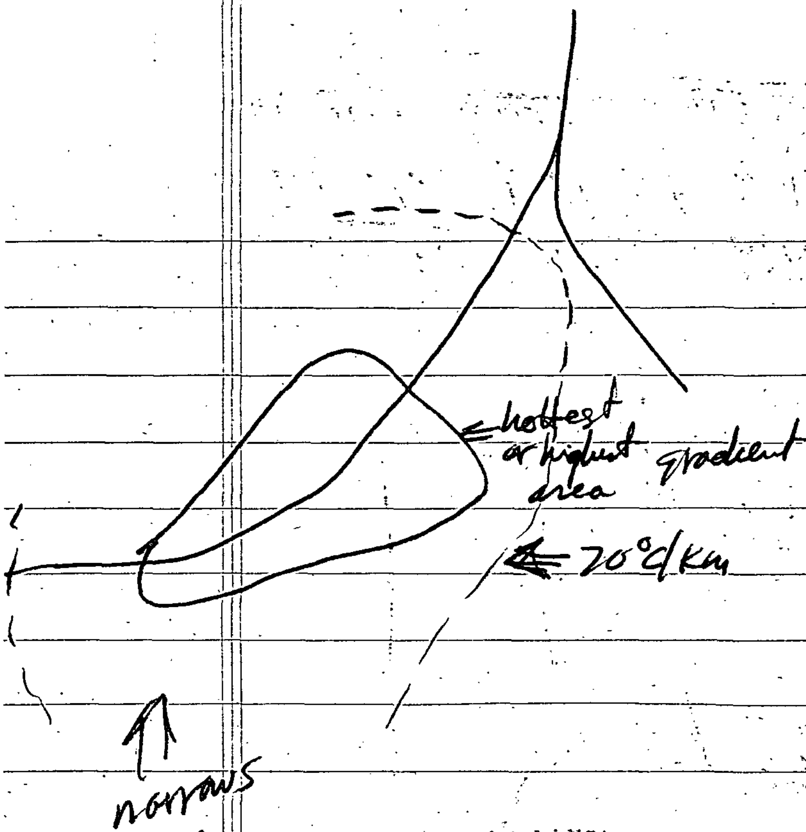
interprets curvature to be "marking upward flowing water"

RRGE-3



believes this is flow up one leg and down another leg

— 77 & 78 — USGS drilled series of holes to see how Raft fits into regional scheme — not to pick holes @ reservoir —



The narrows is a pervasive zone of ~~hot~~ water flow

Na-K-Ca temps of flowing wells agree pretty well w/ measured temps
but for deep wells, Na K Ca are too large
-- so out of equilibrium -- also Si appears to be too low

Bill Bonnichsen – Idaho Bu. Mines –

Geol Maps of S ½ of ID @ 1:250K –
East Bennett -- will be published this week –

→ Steve Divine – U of I grad student has actually done the work –

Thin Section Analyses – Steve D. — ask about matrix porosity — correlations -- characterize minerals [illegible]
-- have found 3 fossils – ostracods
-- sees carbonate cementation of seds.

Some seds show anhedral M along bedding

define anomaly area better — Seismic, IP/resist (?)

Source Area, Location of Fractures -- individual area(s)
How far can afford to ~~pump~~ pipe hot water (?)
Tracer tests performed (?)
Are fracts necessary (?) What about zones of matrix porosity?

X-Ray Analyses - Glen Atwood, BSU
- to date only data generation - no conclusions -
- purpose - identify alterations - zeolites & clays
~~used~~ full range clays + zeolites seen -
- samples ~~shown~~ selected @ changes -
a) reg x-ray
b) clay slides by evaporation
glycolate to cause clay expansion - montmorillonite
to separate from chlorite
then heated 1 hr @ 600°C to destroy mont. [illegible]
chlorite
- now quantitative
- now have proposed to interpret -
plot amount & type of alt. in wells to indicate
fractures identification, etc. -
plot x-ray + lith logs on fence diag. -
correlation between rock types & alteration types
- ~~[illegible]~~ they have x-ray data on file -

C. Nichols - there is a real challenge in coordinating work to eliminate redundancy and make sure it all gets done -
- asked them to contact Wilf Elders
⇒ 4 @ 30 , 5 & 6 @ 30 each ← x-rays avail
well # # analyses
- next proposal covers geothermometry

⇒ This project needs a manager to coordinate

Basin Development - Norm Young
Geothermal Act requires permit from Director IDWR before exploration or development -

- Basin was closed 16 years ago due to declines in well levels of 50' over 1952 - 1963. -
- IDWR has accepted DOE's applic for 5 + cuft/sec of geoth devlop water, but are holding applic until it can be shown that the geothermal water is different from near surface water.
- Idaho law prohibits "mining" of ground water
-- currently can't even buy other water rights to divert this much to geoth.
-- A non-consumptive permit could be issued, but would require no consumption incl. evaporation.
-- Actual changes right @ Raft show no declines or actual rises, but this area is the recharge area for the northern valley, which is declining -

Power Plant - Harold Barton -

— he is proj. manager for 5 MWe power plant

goals - to determine economic, environ & tech feasibility of prod of elect power using 150°C resource

a) 5 MWe ⟹ 2-3 MWe on line after in plant uses

b) use geoth fluid for all energy + cooling tower water

cooling tower uses 200-300 gpm

— plant: high & low pressure boiler + preheaters used w/ isobutane - 2 stage turbine generator

construction of all but generator is about ½ way

generator will be delivered in late 1980.

Scheduled startup - Oct 1981 (?) -

1-2-3-5 prod 6-7 inject 4 (?) obs

production

1 2 3 5
650 625 625 650 = 2500 gpm

6 + 7 ⇒ 1800 gpm reinjection –

real requirements 2900 gpm prod
2200 gpm inject.

They are into long-term well testing phase now –
± 500 hr tests usual – have got 72 hr
tests on most

pipeline now being built for ~~RAGE~~ 7 –

well stimulation – to be done July – Sept, w/
decision on more wells Sept –
integrated testing in early 1980 –

Stimulation – higher in priority
or Additional wells

Stimulation – have RGI + Terra Tek involved
in studying which wells for what, etc.

Direct Applications - Schultz

- right now in RUB&R, 0.4 quads could prob be put on line -- 5 quads current use
- Brady HS ≈ 17 MWe plant
- has slide of costs of geothermal

Ore-Ida	.66 $/M BTU	fossil fuel costs are
Marvel City	2.91	
~~Geoth~~ Feed Proc] Onion dehyd]	0.48	+1.80

~~so~~ some are very economic

~~distant piping the \$?~~

Raft River Experiments

a) Dryer Experiments - w/ JR Simplot -- to dry potato peels & products

- Simplot is Idaho's biggest nat gas user
- fluidized bed drying
- dry to 0.2% water w/ protein content preserved - 40-60% protein
- protein material worth \$200-400 / ton
- 1.5-3 yr payback looks likely

good economics

b) Refrig / Air Cond.
- 4 quads/yr market avail. for penetration
- use 170-190 °F resource needed
- LiBr solution used because it has strong affinity for water
- 56000 Btu/hr geoth heat gets 36000 Btu/hr cooling
- this is first unit of its kind in US

c) Fluidized Bed Space Heater -
sand in bed to scrub heat exchanger
- they will continue work in heat exchangers -

d) Irrigation ~~& Aquaculture~~ -
- if sprinkle irrigation, some foliage surfaces pick up Fl, but in flood irrig, no Fl pickup in plant
- no heavy metal pickup seen to date -

e) Aquaculture -
there is a very good market for fish -
pond culture / raceway culture
catfish + carp - tanks in ~~po~~ buildings, outside raceways & ponds
- have a control group in UI @ Moscow - - identical things happen to both -
- see accelerated growth rates in geoth water - -
can keep better temp control in geoth
25-30% faster than control
- ~~[illegible]~~ geoth fish totally disease free
- due to old water not containing virus etc.

aquaculture is very fluid intensive
Yr 2006 class first yr, need recognition —
-- obvious power plant cascade uses —

Log Analyses — Jim Applegate
- been looking at RR well logs on CASL funding
- to date, have looked at cross plots
-- can't rely on pet and calibrations —
- 4 components of rock
matrix, alt products, primary (pore), secondary (fract)
(sonic, density, neutron
logs responds) porosity

Sonic — are mylies time average response

$$\Delta T = \frac{1}{V} = \frac{\phi_P}{V_W} + \frac{K_c \phi_F}{V_W} + \frac{F_M}{V_M} + \frac{F_{AP}}{V_{AP}}$$

$$\phi_P + K\phi_F + \quad = 1$$

Neutron - measures pore porosity, fract
+ bound water in minerals -

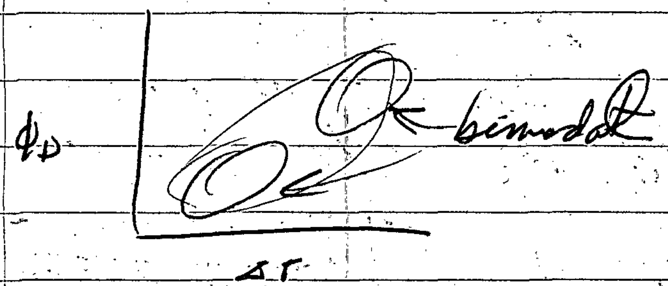
Density -

This all yields 6 unknowns & 5 equations -

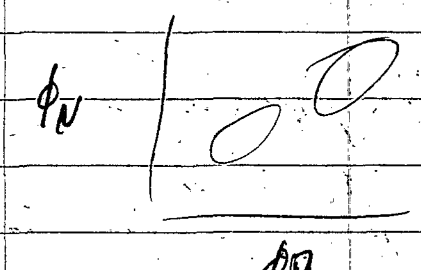
Holes 1, 2, 4 been primary work so far -

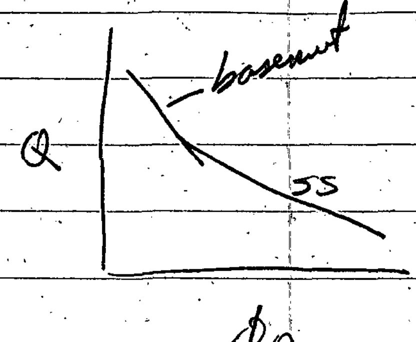
Cross Plots

ϕ_D = density porosity
ΔT from sonic



defines $Q = \frac{\Delta T + \phi_N}{\phi_N}$ (?, ?)





believe we are seeing two different porosities

Qtzte & Qtz may have same Q vs ϕ_D response

- they are beginning to see patterns which allow general rock types -
X-plots may allow different porosity types -
- they will correlate w/ alteration data -
will relate to lithology in more detail
- progress made so far OK, but need to understand model better -
- - schedule for completion

Groundwater - Jerry Crosthwaite - consultant -
- concerns non-thermal groundwater resources
- princip aquifers: Dol, Raft Fm, upper Salt Lake Fm -
typical prod. 800 gpm 1200 gpm 1500 gpm
water level reg or sometimes artesian -

- water comes from Alno Yard valley, there narrows, recharges aquifers
- there is thread water ledge for the V
- 17000 acre feet flows from upper basin to lower
- evapotranspiration takes care of 3/4 this - greasewood grows in areas where GW within 35' of surface -

- recharge of V aquifers is slow in flow better basis -
- there is a subsidence feature N of area - near Malta - is linear, a projection of a USGS fault - due to ~~any~~ differential compaction

Geochemistry - Toraly Allen -
Objective - develop model of resource using water chemistry data -
Ca, K, Li, Mg, Na, SiO2, Br, Cl, F, SO4, pH measured
- these show explainable correlation. -
contents are low in Bridge fault area, higher @ S end valley

- (chloride/fluoride plots done)

- also measured conductivity
  in Bridgeport area 6,000 ±) (highly variable
  to East 12,000 ±) in [illegible] areas)

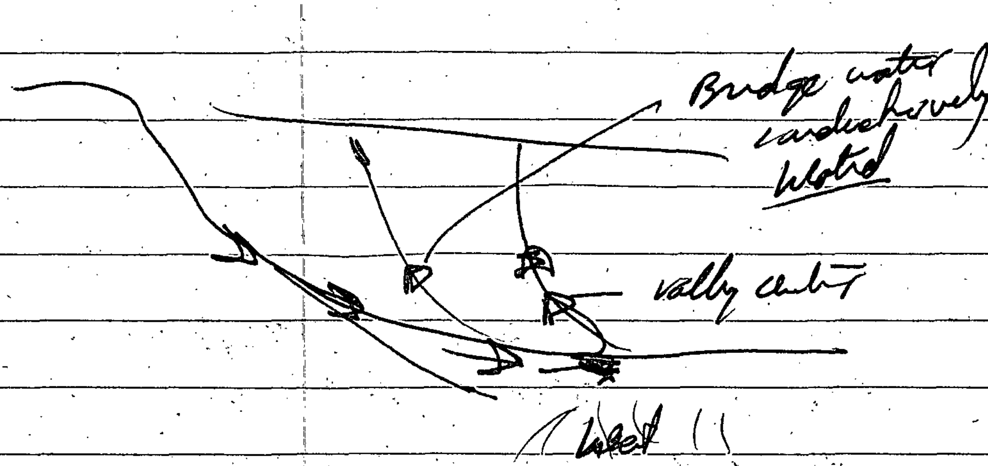
- gypsum & lime water transported westward from deep system to shallower depth [illegible] — water decreases in salinity as it moves west —

- compared [illegible] concentrations to check on mixing models assumptions — got errors 12-20% ; within SD for [illegible] ions. in general, predictions are a bit high —

- what do we know?
a) two types of water - one in valley center, 1 along Bridgeport fault
b) upwelling of geoth waters in both areas, w/ valley center area having both higher temp —
c) Postulates
   deep circulation of water rising near surface along joint, fault zones

Cont

- 2 sources of heat
- primary heat source E & S of dendys
- conduction heating of Bridge fault water
- ground-water, get water away



Reservoir Eng - witherspoon

- Talked about tidal effects in reservoirs
  - storeitivity can be related to measured pressure changes
  0.2 psi peak-to-peak typical variations measured

$\frac{S_s}{\phi}$ = computed S_s = specific stor
ϕ = Porosity

need way to get transmissivity

- capacity to produce is pretty well proven
- he says that if communications exist between shallower and deeper reservoirs, then this is very important because Paul's calculations so far assume no communication.

- Tracers - looking @ fluorcarbons because they can be injected in ppm and detected in ppb -
RGI is getting ready to develop a tracer for stimulations work @ RR -

Dave Allman – Reservoir Engineering/Testing

Objectives – a) fluid properties
b) production properties
c) interaction w/ shallow water

- regions of producing and receiving fluid in holes (1366 ft of uncased sections) are unknown –

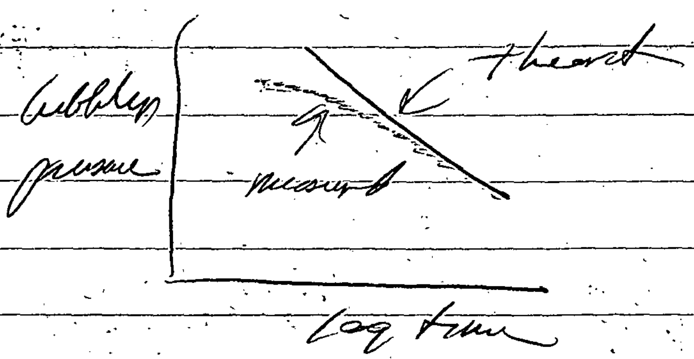
RRGE-1 – 3682-4999' prod zone
- pump tests have allowed prediction for 5 years of production

gpm	psi drawdown	
600	225	T=280°F
1200	452	

RRGE-2 T=283°F max wellhead temp
4227-6543 uncased portion
a) cold water injection shows 3 zones of production
- first couple of hundred minutes of testing are NG because things have not come to equilibrium yet –
- calculates Δf_{50} –
- plots bubbler pressure vs log time, gets straight lines of diff slopes indicating diff lithology, etc.

- interference was noted to date -

RRGE-3 p 126 psig Sb MT = 296°C
4255-5929 prod zone
- prod mainly Cg C
- ~~highest recently [illegible]~~
- [illegible]



pump tests

calculated recovery is also noted

- pump tests
drawdown plot
3335 [illegible]
8 [illegible]

also has been
some of injection

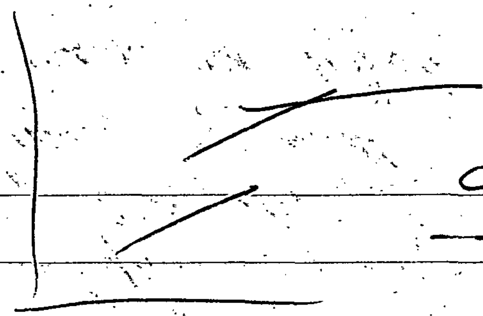
for production wells -
- pumping costs are small compared with in-plant pumping costs

RRGP-4B T-289°F
3470-5224 uncased borehole logs
-5228 logs
Very poor production - 15 gpm

- this is a good candidate for stimulation
- this may be quantity of water can expect to get ~~from~~ unfractured seds -

RRGP-5B
T = 273°F - coldest production well
equivalent recharge boundary @ 100 min.
- plans to pump @ 250 gpm

RRGI-~~3~~-6
T = 252°F uncased 1698-3888 ft
shallowest and well @ RR -
- caving borehole just below casing
- possible interference w/ -7
- its a good injection well
1 major receiving zone in well
- hit a recharge area which causes pressure



different segments

RR GI-7

2044-3858 T=200°F+

little interference w/ RRGI-6

Conclusions

1. could get 2500-3200 gpm - need bigger pump
2. inadequate injection capacity
3. Temps 223 Bridge
   290 Narrows