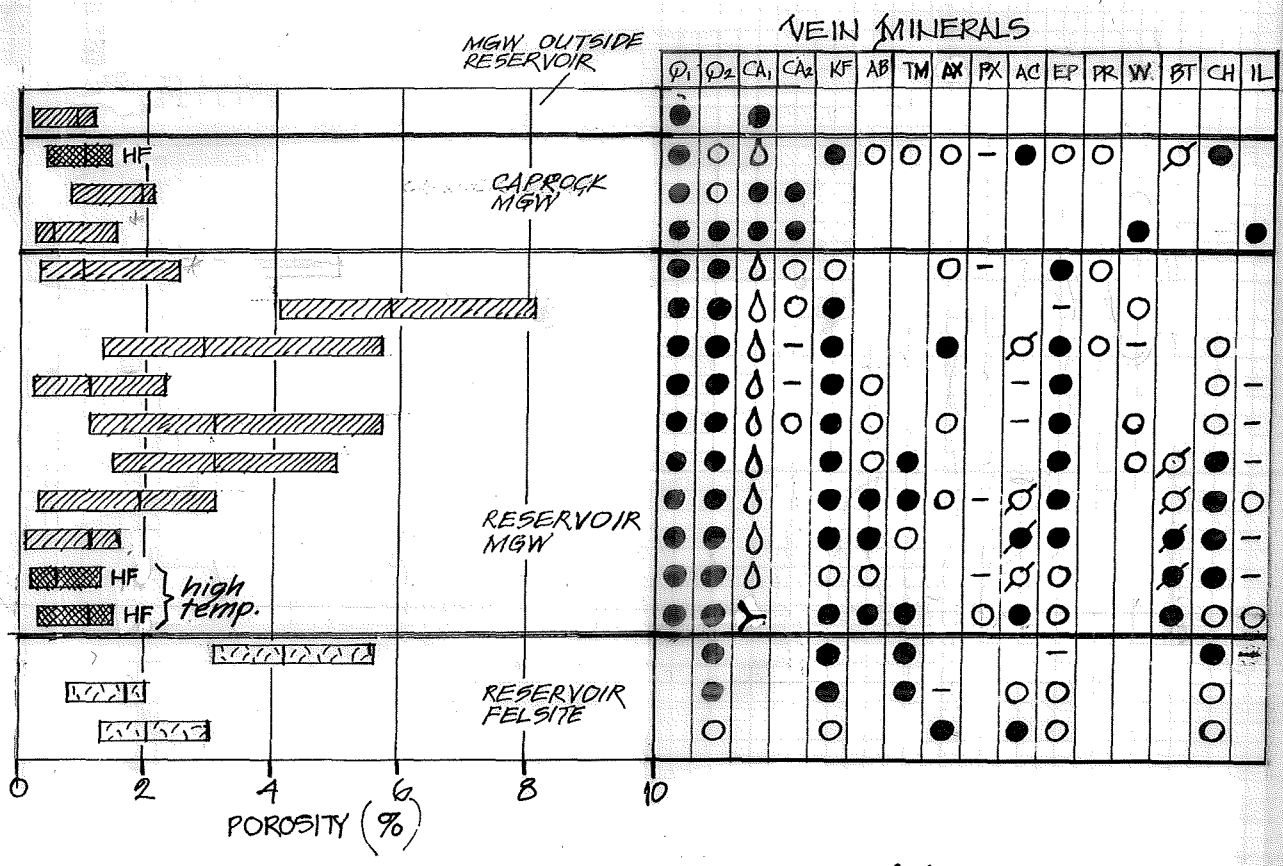
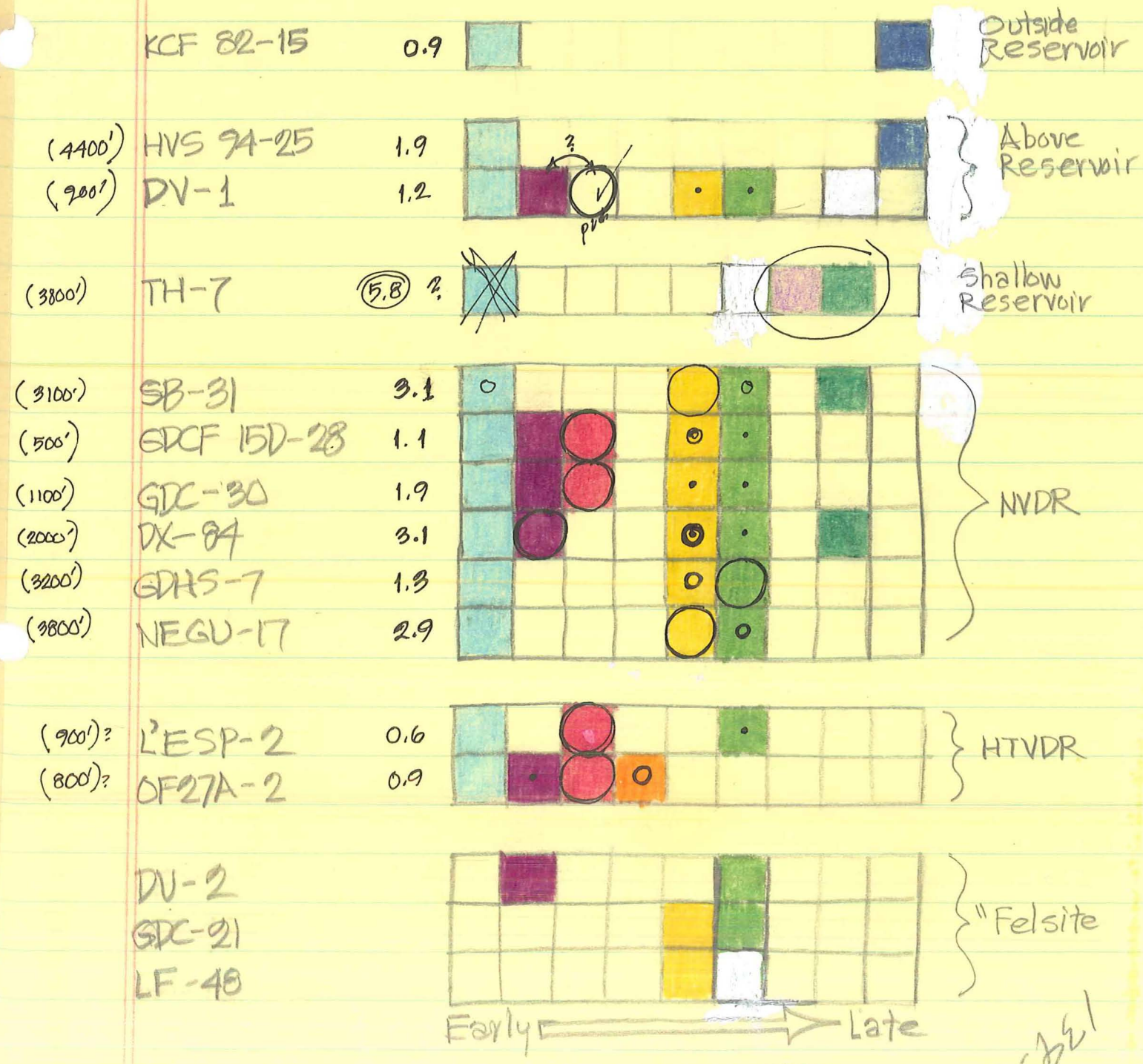
GL04893



MGW – METAGRAYWACKE
HF – HORNFELSIC

● MAJOR ◐ REPLACED WITH CHLORITE
○ MINOR – TRACE
◊ >95% HYDROTHERMALLY DISSOLVED
≻ METAMORPHIC RECRYSTALLIZATION TO CALC-SILICATE PHASES

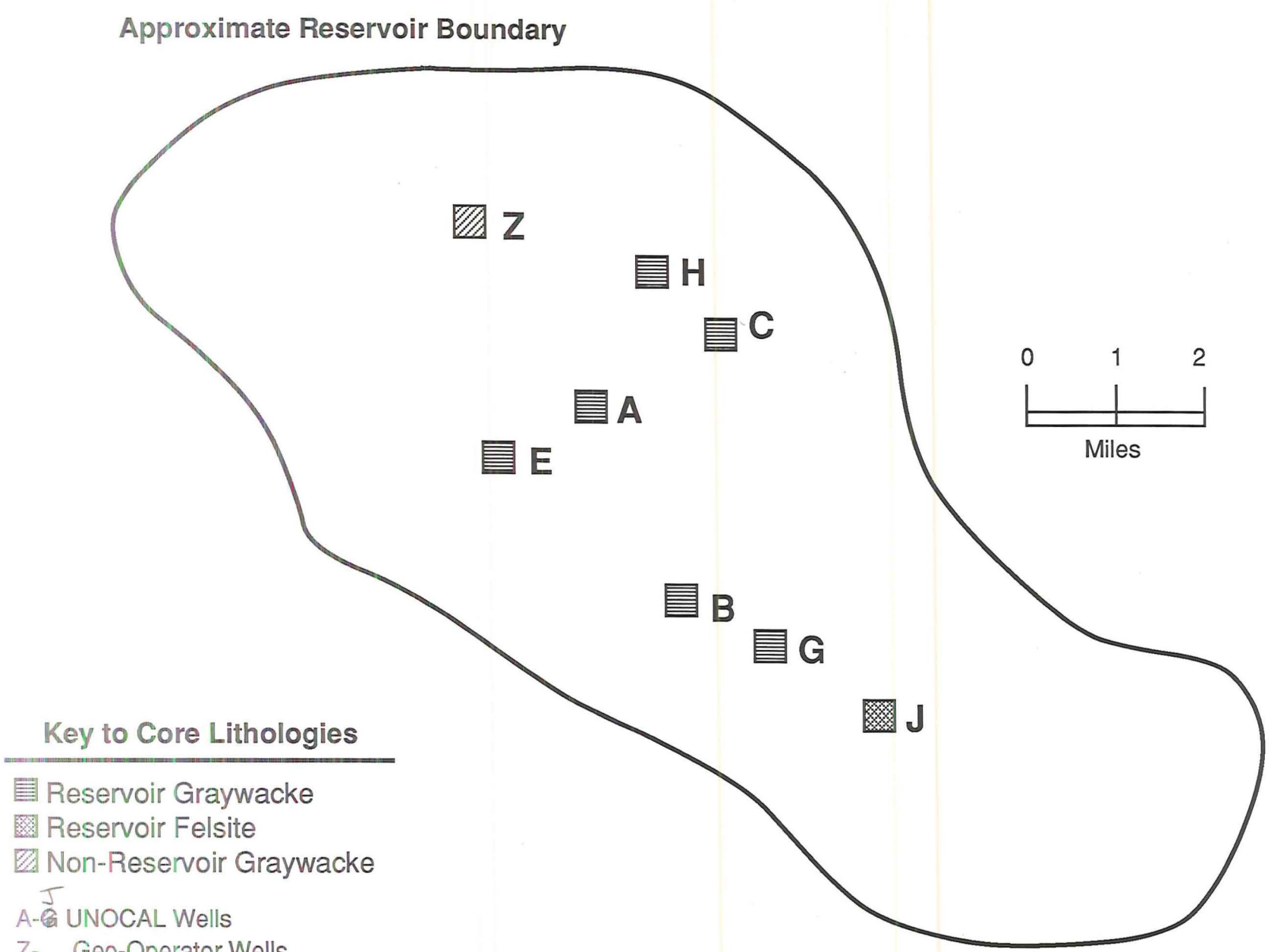
THE GEYSERS, 15 CORES
Paragenetic Summary

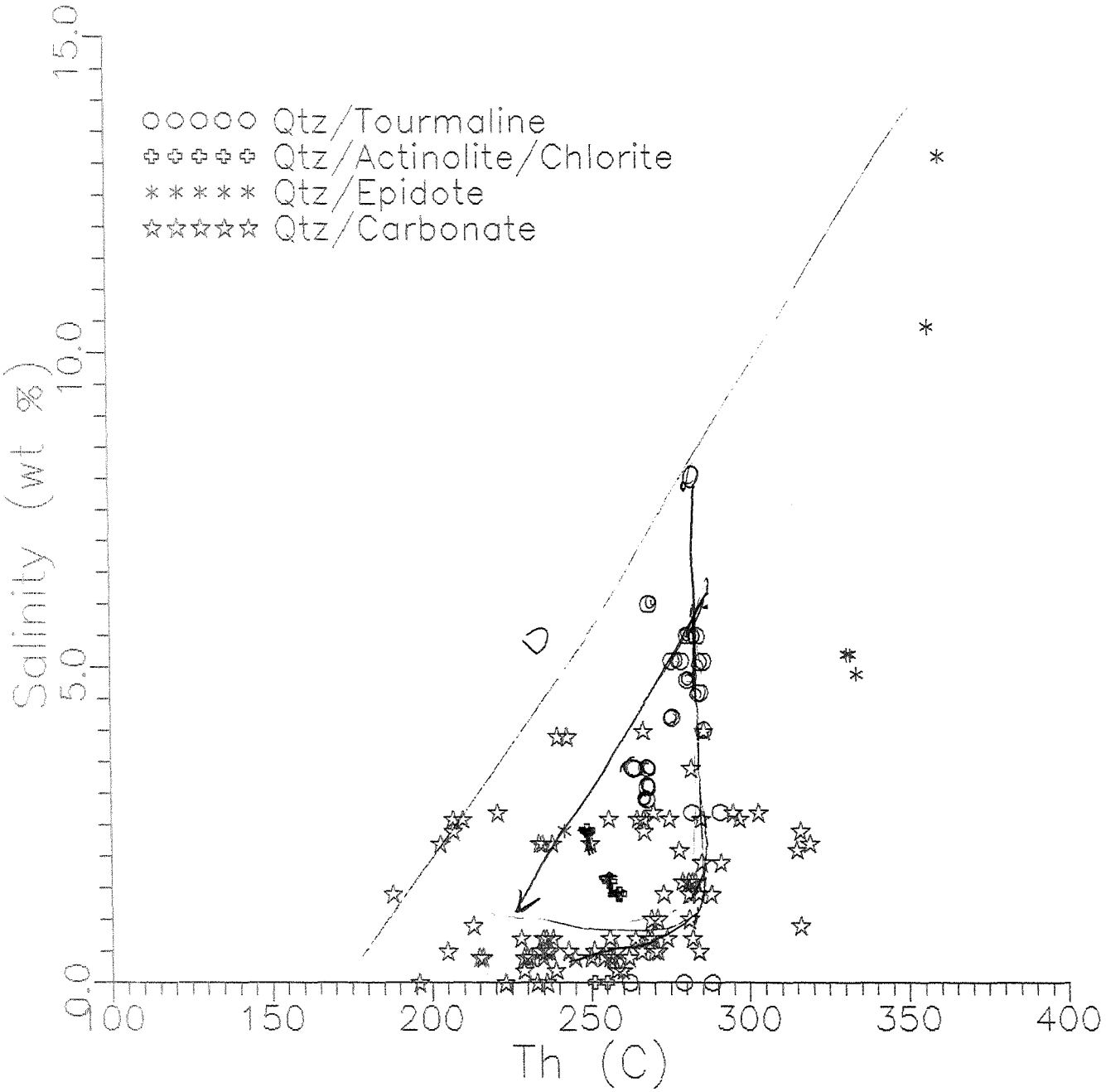


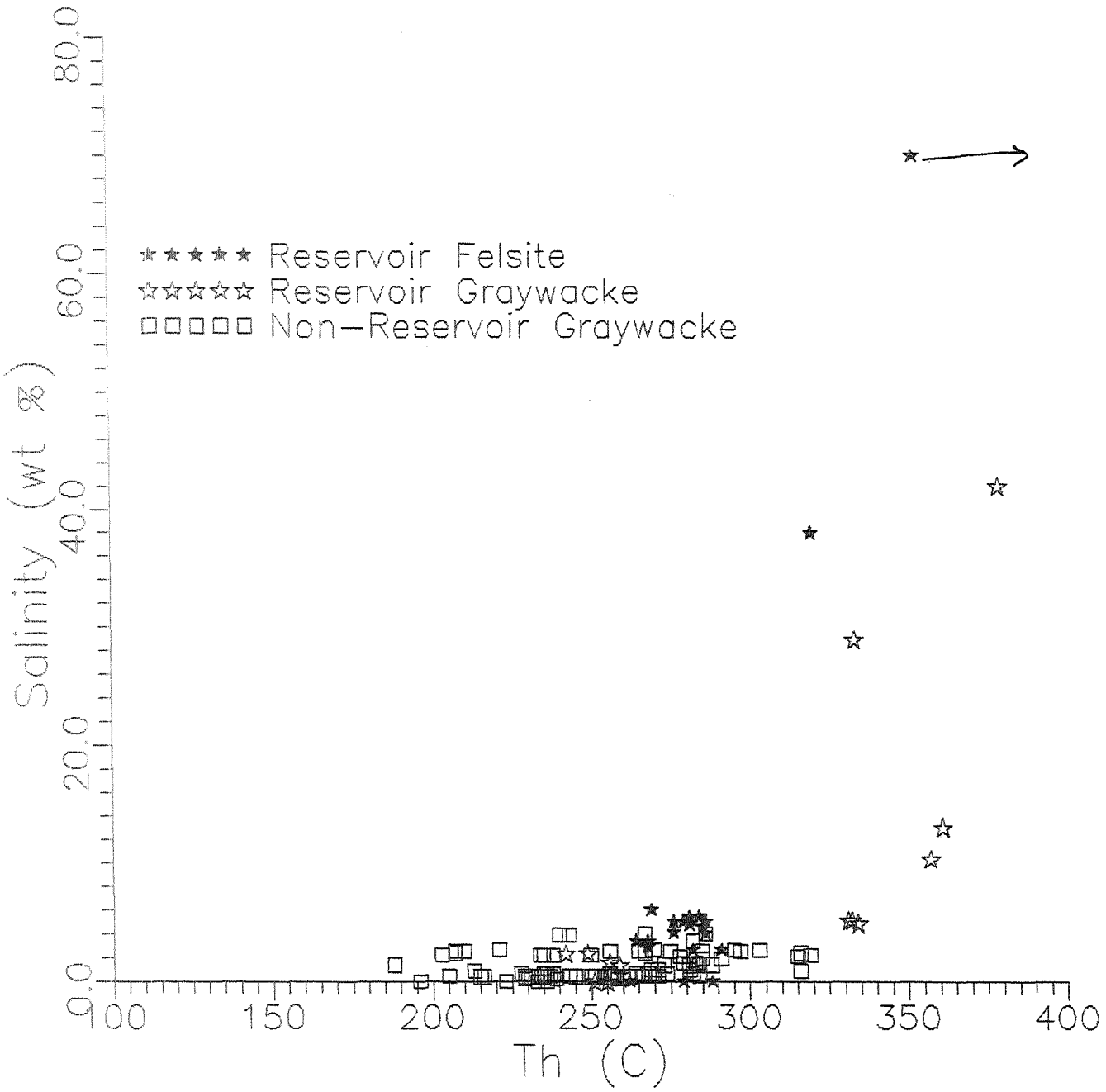
JBH/LLURI/1991

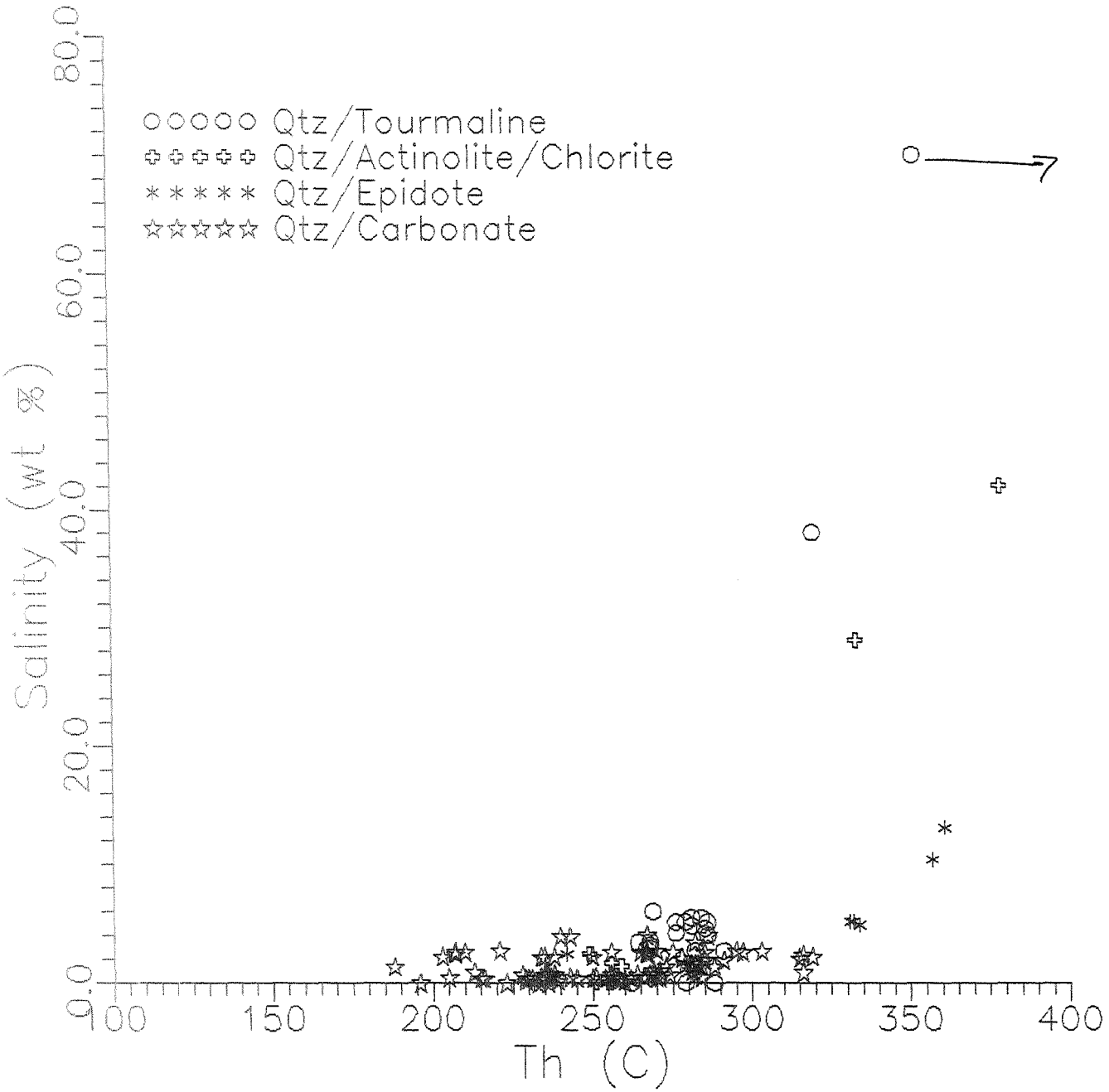
Core Chloride Data

Well	Sample from	Core Interval (drld ft)	Core Elevation (MSL)	Felsite Elevation (MSL)	Rock Type
DX-84	reservoir	7730-7741	-4180	-6200	graywacke
GDC-30	reservoir	5012-5022	-2920	-4000	graywacke
GDHS-7	reservoir	8060-8075	-4825	-8000	graywacke
NEGU-17	reservoir	8523-8540	-5245	-9000	graywacke
SB-31	reservoir	3729-3750	-1565	-4700	graywacke
TH-7	shallow reservoir	1000+-	740	-4500	graywacke
GDCF 15D-28	reservoir	5017-5032	-2015	-2500	graywacke
L'ESP-2	high-T reservoir	11051-1106	-8075	-9000	graywacke
OF 27-A2	high-T reservoir	10366-1038	-7225	-8000	graywacke
DV-2	steam entry	3708-3718	-665	-300	felsite
LF-48	reservoir	8089-8096	-4805	-3000	felsite
DV-1	above reservoir	4140-4150	-1295	-2200	graywacke
HVS 94-25	above reservoir	8234-8248	-5595	-10000	graywacke


Approximate Reservoir Boundary
Z
H
C
A
E
B
G
J
0
1
2
Miles
Key to Core Lithologies
Reservoir Graywacke
Reservoir Felsite
Non-Reservoir Graywacke
A-G UNOCAL Wells
Z- Geo-Operator Wells


Qtz/Tourmaline
Qtz/Actinolite/Chlorite
Qtz/Epidote
Qtz/Carbonate
Salinity (wt %)
15.0
10.0
5.0
0.0
100
150
200
250
300
350
400
Th (C)


Reservoir Felsite
Reservoir Graywacke
Non-Reservoir Graywacke
Salinity (wt %)
80.0
60.0
40.0
20.0
0.0
100
150
200
250
300
350
400
Th (C)


○○○○○ Qtz/Tourmaline
✣✣✣✣✣ Qtz/Actinolite/Chlorite
***** Qtz/Epidote
☆☆☆☆☆ Qtz/Carbonate
Salinity (wt %)
80.0
60.0
40.0
20.0
0.0
100
150
200
250
300
350
400
Th (C)

General Features of the Veins and Fluid Inclusions

Vein Types

Quartz + Calcite (Franciscan)
Quartz + Tourmaline + Actinolite + Chlorite
Quartz + Actinolite + Epidote + Chlorite
Quartz + Epidote
Quartz + Calcite + Adularia

Fluid Inclusion Types

Liquid-rich Inclusions (Oldest to Youngest)
- 4 Phases with Halite and Sylvite
- 3 Phases with Halite
- 2 Phases with less than about 5 Wt % Co2

Vapor-rich Inclusions

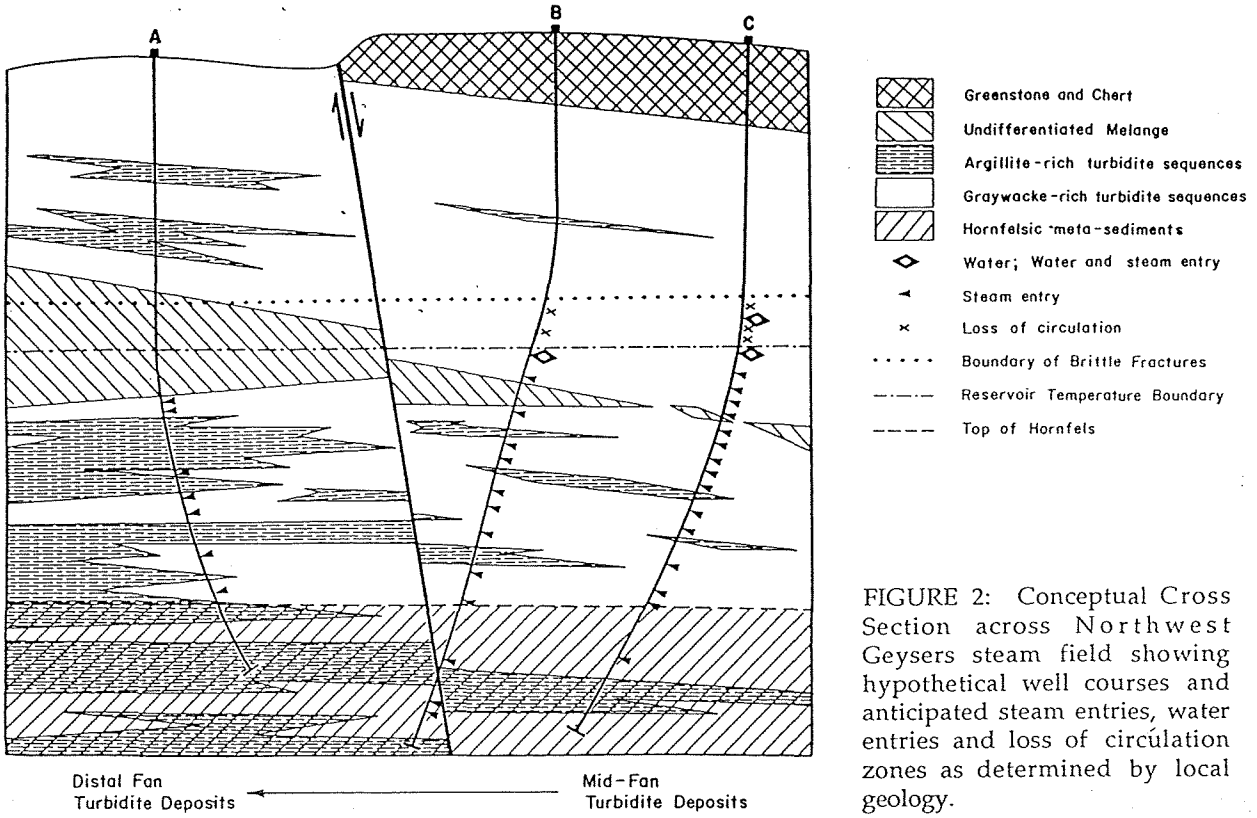


FIGURE 2: Conceptual Cross Section across Northwest Geysers steam field showing hypothetical well courses and anticipated steam entries, water entries and loss of circulation zones as determined by local geology.

GUNDERSON

TABLE 1

Well	Sample From	Core Interval (Drilled Depth)	Core Elev. (MSL)	Felsite Elev. (MSL)	Rock Type	Porosity (vol %) 4" Core	Porosity (vol %) 1" Plug	Porosity (vol %) Range of Values	Grain Density (g/cm^3)
A DX-04	Reservoir	7730-7741'	-4180'	-6200	Graywacke	3.1	3.2	1.5-5.0(12)	2.70
B GDC-30	Reservoir	5012-5022'	-2920'	-4000	Graywacke	1.9	1.4	0.3-3.1(12)	2.71
C GDHS-7	Reservoir	8060-8075'	-4825'	-8000	Graywacke	1.3	1.1	0.2-2.1(12)	2.74
D NEGU-17	Reservoir	8523-8540'	-5245'	-9000	Graywacke	2.9	2.6	1.1-5.6(8)	2.72
E SB-31	Reservoir	3729-3750'	-1565'	-4700	Graywacke	3.1	3.1	1.1-5.7(16)	2.72
F TH-7	Shallow Resv.	~1000'	~+740'	-4500	Graywacke	---	5.8	4.1-8.1(10)	2.69
G GDCF 15D-28	Reservoir	5017-5032'	-2015'	-2500	Graywacke	1.1	0.6	0.1-1.6(8)	2.69
H L'ESP-2	High-T Resv.	11,051-11,067'	-8075'	-9000	Graywacke	0.6	0.7	0.2-1.1(8)	2.74
I OF27A-2 ST1	High-T Resv.	10,366-10,387'	-7225'	-8000	Graywacke	0.9	0.8	0.3-1.5(8)	2.75
J DV-2	Steam Entry	3708-3718'	-665'	-300	Felsite	4.2	4.4	3.1-5.6(4)	2.63
K GDC-21	Reservoir	5064-5068'	-3310'	-1500	Felsite	1.7	0.8	0.8-2.0(4)	2.65
L LF 48	Reservoir	8089-8096'	-4805'	-3000	Felsite	2.1	1.6	1.1-3.0(8)	2.62
M DV-1	Above Resv.	4140-4150'	-1295'	-2200	Graywacke	1.2	0.6	0.4-1.4(5)	2.70
N HVS 94-25	Above Resv.	8234-8248'	-5595'	-10,000	Graywacke	1.9	1.4	0.8-2.1(5)	2.71
P KCS 82-15	Outside Resv.	10,065-10,087'	-7670'	---	Graywacke	0.9	0.3	0.2-1.2(5)	2.78
Q Shallow Cores	Above Resv.	<200'	+3000'	---	Graywacke	---	2.3	1.0-3.2(5)	2.73

each core is recovered as segments of full 4 inch diameter, with the remainder ranging from only slightly broken pieces to rubble.

The twelve reservoir cores include eight cores of graywacke from the main reservoir, one graywacke core from the shallow Thermal reservoir (Raasch, 1985), and three cores of reservoir felsite. Depths of these cores range from about 1,000 feet to 11,067 feet. For comparison of reservoir porosities with porosities outside the reservoir, four non-reservoir graywacke cores were analyzed. Those include two cores of reservoir cap rocks, one deep core from a well entirely outside the reservoir, and five very shallow cores from within a few hundred feet of the surface. Locations of the deep cores are shown in Figure 1.

ROCK POROSITIES

Matrix porosity was determined for all samples at Terra-Tek Core Services, Inc. of Salt Lake City by comparing grain volume, measured by permeating the rock with helium, with bulk volume, measured by immersion in water or mercury. The resultant values represent effective porosities applicable to a vapor-dominated geothermal reservoir, since they are measurements of that part of the rock which is permeable to a low viscosity gas phase (i.e. steam). Multiple porosity measurements were made on each core to determine an average value of porosity. The measurements were taken wherever possible on both full diameter 4-inch core and 1-inch diameter plugs which were cut from

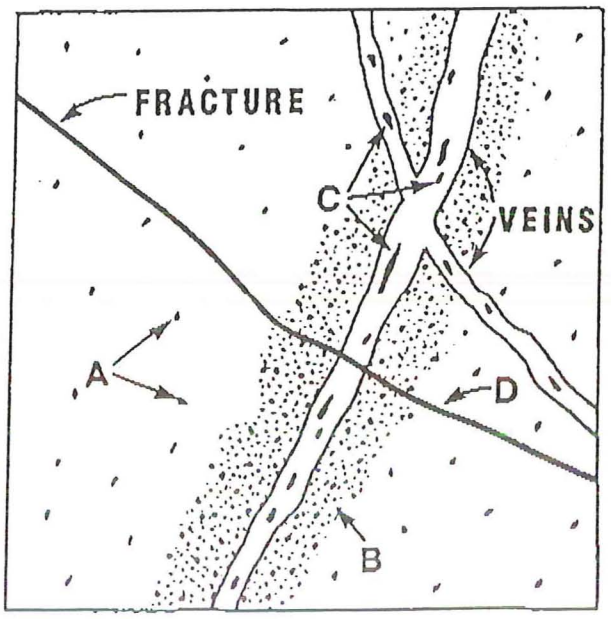


Figure 2: Schematic diagram depicting the four types of matrix porosity recognized in Geysers cores.
A. widely distributed vugs and intergranular voids,
B. concentrations of vugs and intergranular voids associated with vein selvages,
C. vugs within veins,
D. young, unmineralized fractures.

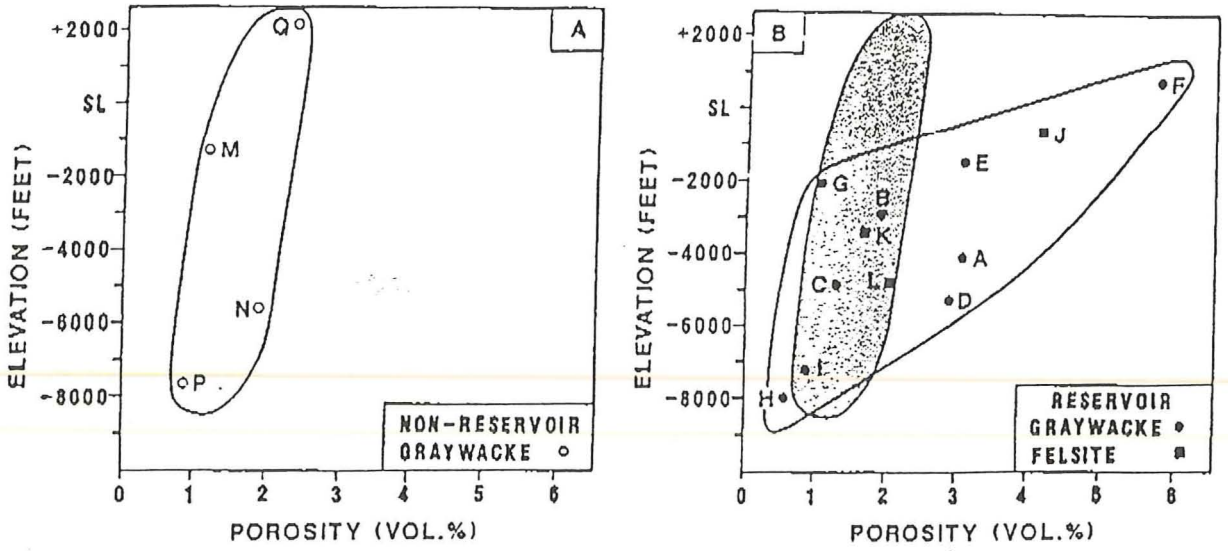


Figure 3: A: Distribution of porosity with depth in Geysers area non-reservoir graywacke cores.
B: Distribution of porosity with depth in Geysers reservoir cores. The shaded area is from 3A. Core names are keyed to Table 1.

the core. The results are presented in Table 1.

In 10 out of the 14 cores where porosity was measured on both 4-inch and 1-inch diameter samples, the 4-inch samples yielded higher values (Table 1). The average porosity of the 4 inch samples from those 14 cores was 1.9% and the average 1 inch porosity was 1.6%. The disparity between 1-inch and 4-inch samples suggests heterogeneity in the distribution of porosity at the scale of a few centimeters. This heterogeneity is thought to be a result of the fracture-related nature of the porosity, as seen petrographically (Figure 2). The porosity measured on a 1-inch plug represents a uniformly distributed porosity component (Figure 2: Type A) plus a component related to the fractures in that sample (Figure 2: Types B, C, D). Porosities of 4-inch cores are thought to be higher than 1-inch porosities because, by virtue of their larger volumes, they sample additional larger, more widely spaced fractures and hence have a larger fracture-related porosity component. It follows that matrix porosities applicable on a reservoir scale (where all fractures smaller than steam entry-sized fractures contribute to matrix porosity) would be higher still than those measured in the 4-inch core. Lacking a way to sample larger volumes of the reservoir, the 4-inch porosities will be used hereafter in this study (where available). They are probably closer to reservoir values than are the 1-inch porosities.

Geysers rocks have very low porosities when compared to most other geothermal reservoir rocks; however, there appears to be higher porosity and more variation of porosity in reservoir graywacke than in graywacke from outside of the reservoir. Porosities of reservoir graywacke cores vary from a low of 0.6% to a high of 5.8% (Table 1). In contrast, non-reservoir graywacke vary only from 0.9 to 2.3%. The two "matrix" felsite values are very similar at 1.7% and 2.1%.

The difference in porosities between graywackes inside and outside the reservoir is highlighted in Figure 3. In non-reservoir graywackes there appears to be very little variation of porosity with depth (Figure 3A). Reservoir graywackes, while they show considerable overlap with non-reservoir porosities, clearly show much more variation and have a more positive correlation with depth (Figure 3B).

The wider range in porosities of reservoir rocks when compared to non-reservoir rocks suggests that processes which have both enhanced and destroyed porosity have occurred in the reservoir. Processes enhancing porosity probably included

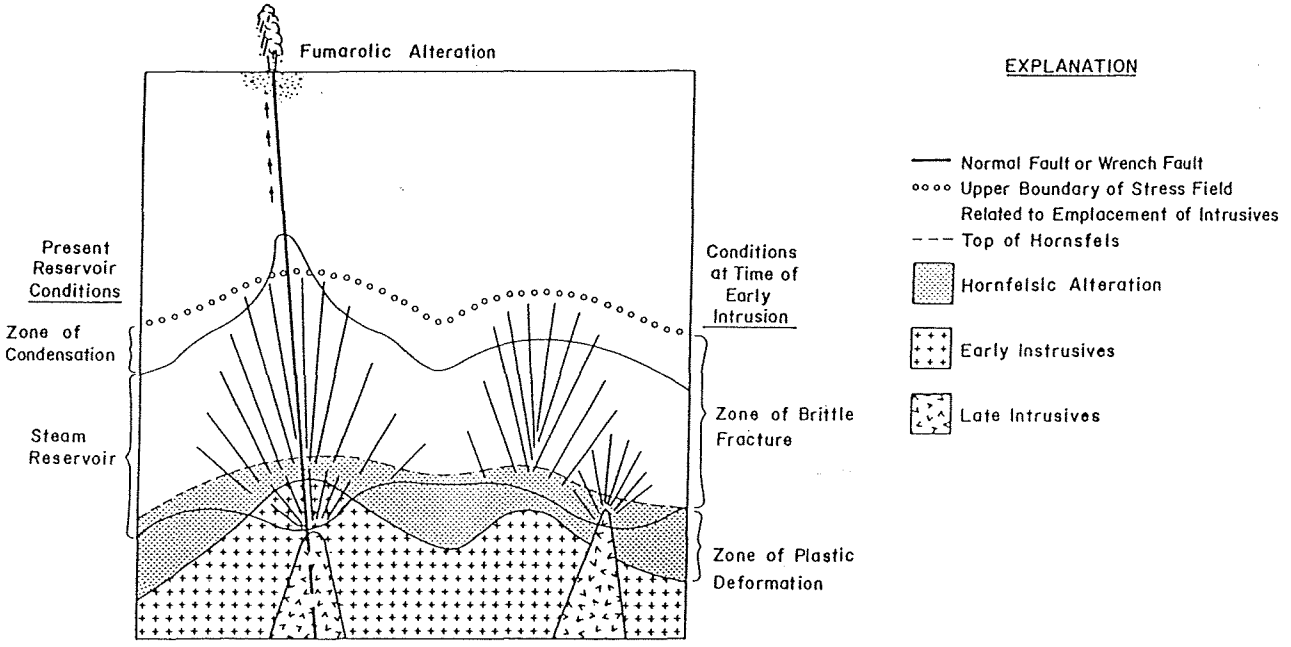


FIGURE 3: Idealized model for fracture generation and distribution of steam.

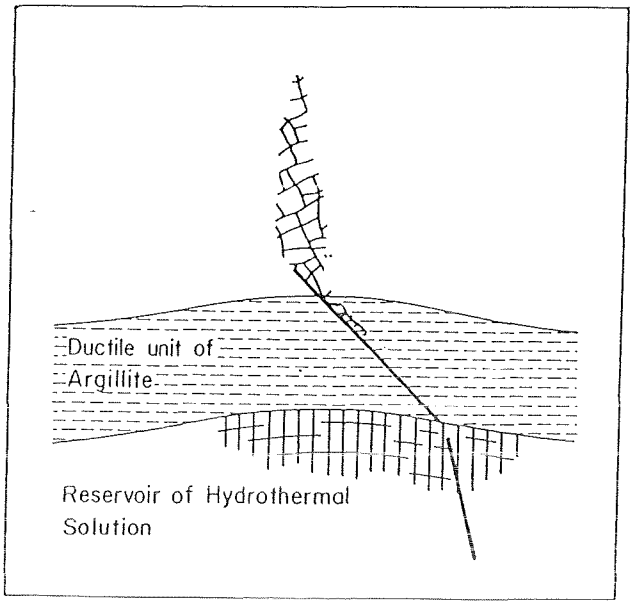
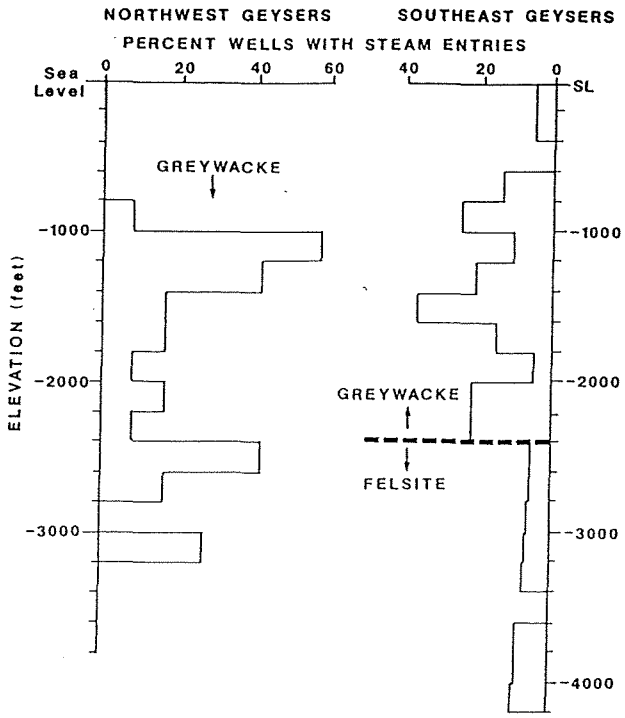
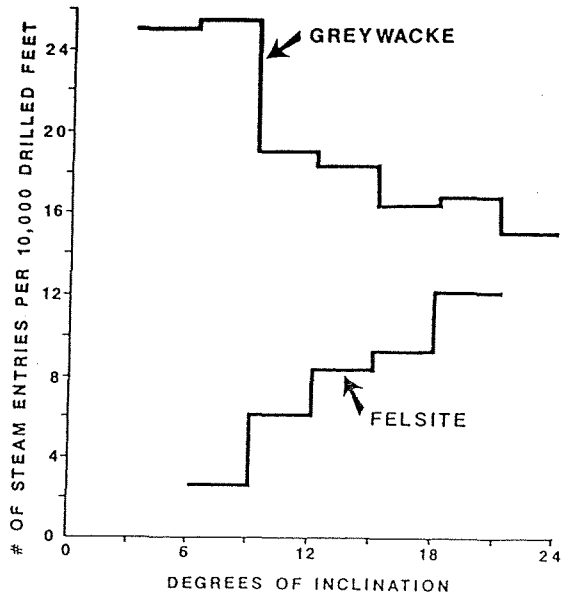
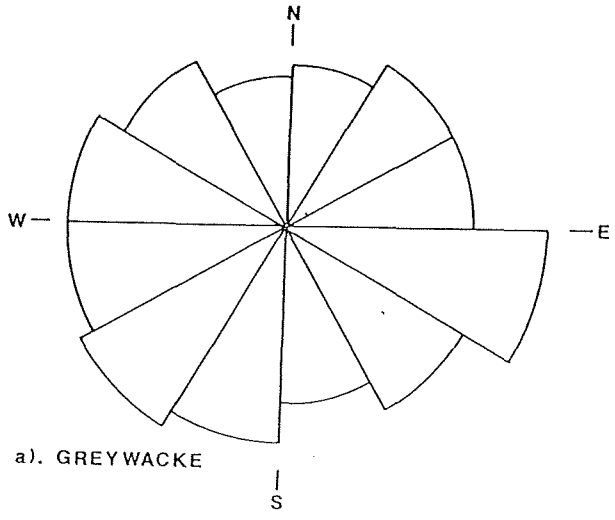


FIGURE 4: Interpreted effects of argillite bed on hydraulic fracturing. Modified from Phillips, 1972.

THOMPSON & GLINDERSON, 1989, GRC TRANS., 13







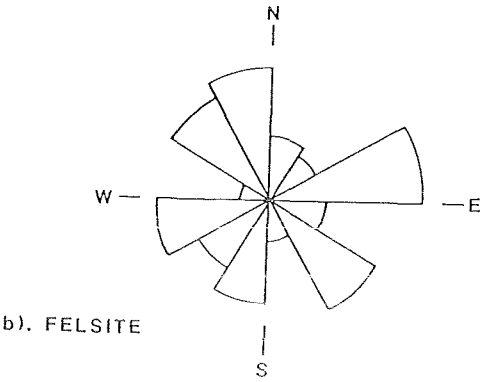


Figure 6. Rose diagrams of steam entry frequency versus well azimuth direction. Length of slice proportional to frequency (number of entries divided by feet drilled). Data calculated from tabulation of well azimuth directions at each steam entry intersection and total reservoir footage drilled in each azimuth direction. a) Data from greywacke reservoir rocks. b) Data from felsite reservoir rocks.

Abstract

The Geysers steam reservoir exists primarily within Mesozoic Franciscan greywacke and an underlying 2.4 - 0.9 Ma silicic batholith. All steam from both reservoir rock types is produced from a highly permeable and interconnected set of fractures. The top of the reservoir has a roughly antiformal shape, with a northwest-trending axis that coincides with the axis of the elongate batholith.

Different fracture patterns exist in the greywacke and intrusive rocks. The orientation of steam-bearing fractures within greywacke is generally random, but includes extensive low-angle fracture zones. We infer from this that many of the fractures represent re-opened Franciscan-age structures. The distribution of these steam-bearing fractures in greywacke leads to laterally extensive zones of high productivity. In contrast, high productivity in the intrusive rocks is found in narrow, steeply-dipping zones. This pattern reflects the predominantly high-angle fractures in the intrusive rocks that are related to recent strike-slip tectonics.

BEALL & BOX, 1989, GRC TRANS., 13,

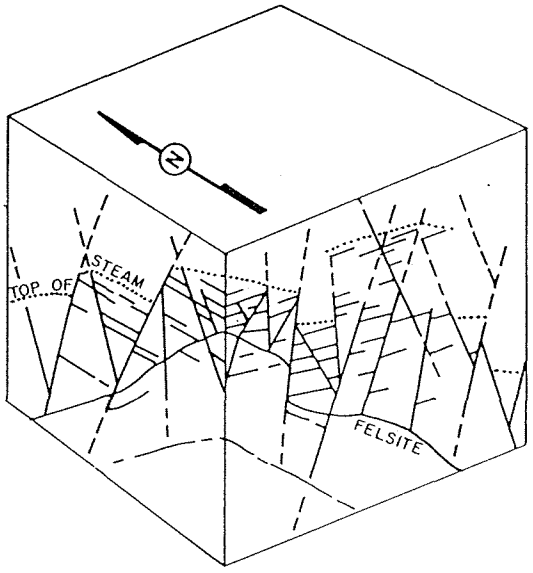


Figure 9. Schematic representation of the fracture system contained within the South Geysers reservoir. View is to the northeast from immediately southwest of the Unit 13 area.

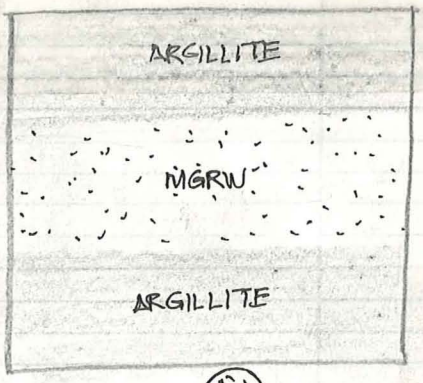
ABSTRACT

The distribution of steam bearing fractures in over 100 wells in The South Geysers reservoir indicates an effectively random fracture network. Low angle productive fractures of limited lateral extent are irregularly dispersed within blocks bounded by high angle fractures of random strike. The upper surface of the reservoir exhibits major vertical offsets at block edges. The lower, and the northeastern and southeastern reservoir margins are gradational in nature and dominated by high angle fractures with diminishing fracture density.

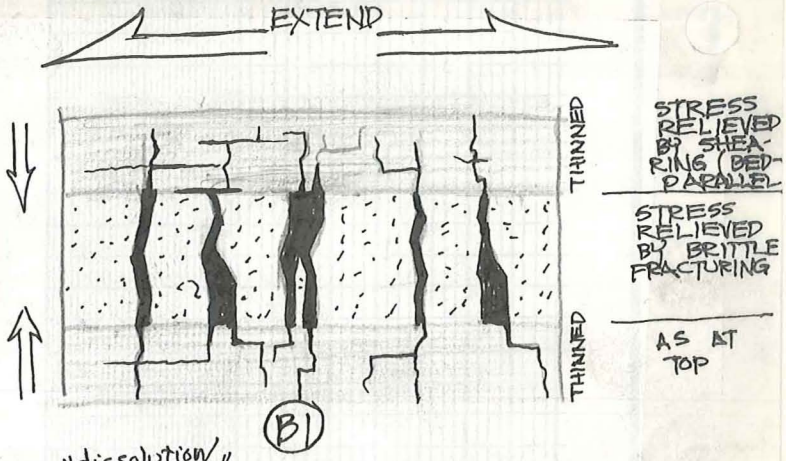
Permeability is enhanced in the north to north-northeast direction as evidenced by tracer studies. This is compatible with the stress field orientation in The Geysers as determined from seismic studies.

CONCLUSIONS

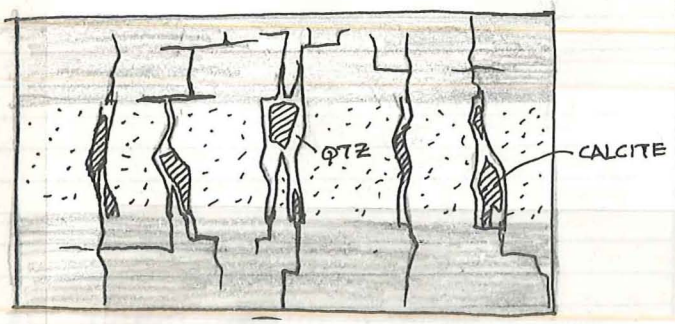
The current study indicates that the distribution of reservoir fractures is largely random. The reservoir model which best fits our data is one of vertical to high angle fractures of varying strike, defining blocks which contain low angle fractures of limited lateral extent. Block size is highly variable, as is the density of low angle fractures within them. Both the northeast and southeast lateral reservoir boundaries as well as the lower boundary appear to be gradational in nature, with productive fractures being more widely spaced and dominated by the high angle variety. Never the less, it is the generous overall distribution of productive fractures which has been most responsible for the success of development drilling operations in The Geysers.

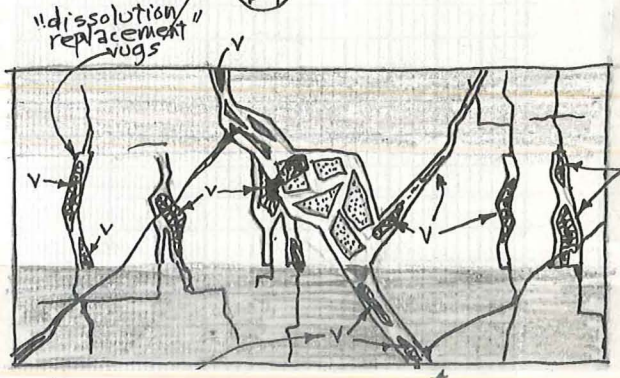


(A1)



(B1)





SCENARIO FOR CREATION OF VUG & VEINLET POROSITY IN THE GEYSERS (BASED ON CORE LOGGING 10/1-10/6/90); modified from Gunderson, 1990

(A1) Interbedded metagraywacke and argillite (sandstone/shale)

(B1) Extension // to bedding (in plane); argillite/shale takes up stress by shearing; MGW/sandstone brittly fractures (tension fractures ⊥ to bedding)

(C1) Fractures mineralized w/ quartz and calcite

(D1) liquid-dominated high-T hydrothermal system superimposed (driven by cooling pluton)

- hydraulic fracturing & hydrothermal brecciation
  → dilation: new open spaces formed
- calcite unstable: dissolved and/or replaced with epidote ± ferroaxinite
  → vugs developed where calcite was
- new vein minerals in fractures & intra(er?)clast spaces in breccias don't totally fill the voids
  → primary intercrystalline vugs formed

*, in interbedded argillite and graywacke

large-volume

note: (B1) the presence of ~~inter~~ thinly interbedded argillite w/ thicker MGW beds might be more conducive to ^ tectonic fracturing than a massive graywacke.

STERNFELD, '89, GRC TRANS., 13

HYDROTHERMAL ALTERATION

The subsurface in the Northwest Geysers can be divided into three zones based on the observed hydrothermal alteration. The first zone is a relatively unfractured and non-productive graywacke above the steam reservoir. This interval is not totally void of hydrothermal mineralization as there are isolated thin breccia zones of adularia-sericite alteration formed by the explosive eruption of boiling hydrothermal fluids (Sternfeld and Walters, 1989; Moore and others, 1989).

The second zone is a hydrothermally altered steam-bearing zone characterized by the disappearance of Franciscan calcite veining and the pervasive deposition of two distinctive generations of hydrothermal minerals (Walters and others, 1988). The most dominant generation of authigenic minerals is composed of successive temperature-dependent assemblages. These are quartz + epidote + albite + pyrite, actinolite + adularia + pyrrhotite, and tourmaline + quartz + hornblendic amphibole + pyroxene + ilmenite. Superimposed over this earlier mineral zonation is the distribution of a second generation of minerals characterized by prehnite and axinite. There is a good correlation between the occurrences of prehnite + axinite and observed steam entries.

The third zone is composed of hornfelsic graywacke which was partially to completely melted and recrystallized by underlying intrusive rocks. This material is composed of a fine to medium crystalline assemblage of biotite + tourmaline + adularia + quartz + ilmenite. Zones of hornfelsic graywacke, 1500 to 2500 ft thick, overlie felsite intrusives rocks in other areas of the Geysers. Even though felsite has not been drilled in the Northwest Geysers, the presence of hornfels indicates the existence of intrusive rocks at a postulated depth of 3.5 km.

RECONNAISSANCE NOTES

Sample Identification	Petrographer/Date of Examination
GDHS-7B	JEFF HULEN 09/26/90

Rock Type strongly sheared, argillaceous, organic-rich LITHIC Metagraywacke

Fracturing/Brecciation/Veining and Vug-Filling frx & bxn just prior to vn. episode (3) below jigsaw-puzzle breccias → vnlts & vugs, filling ep (3) frx & brx. highly dilational, overall a preferred orientation subparallel to Long axis of section with all veins 4-5% of Total TS area

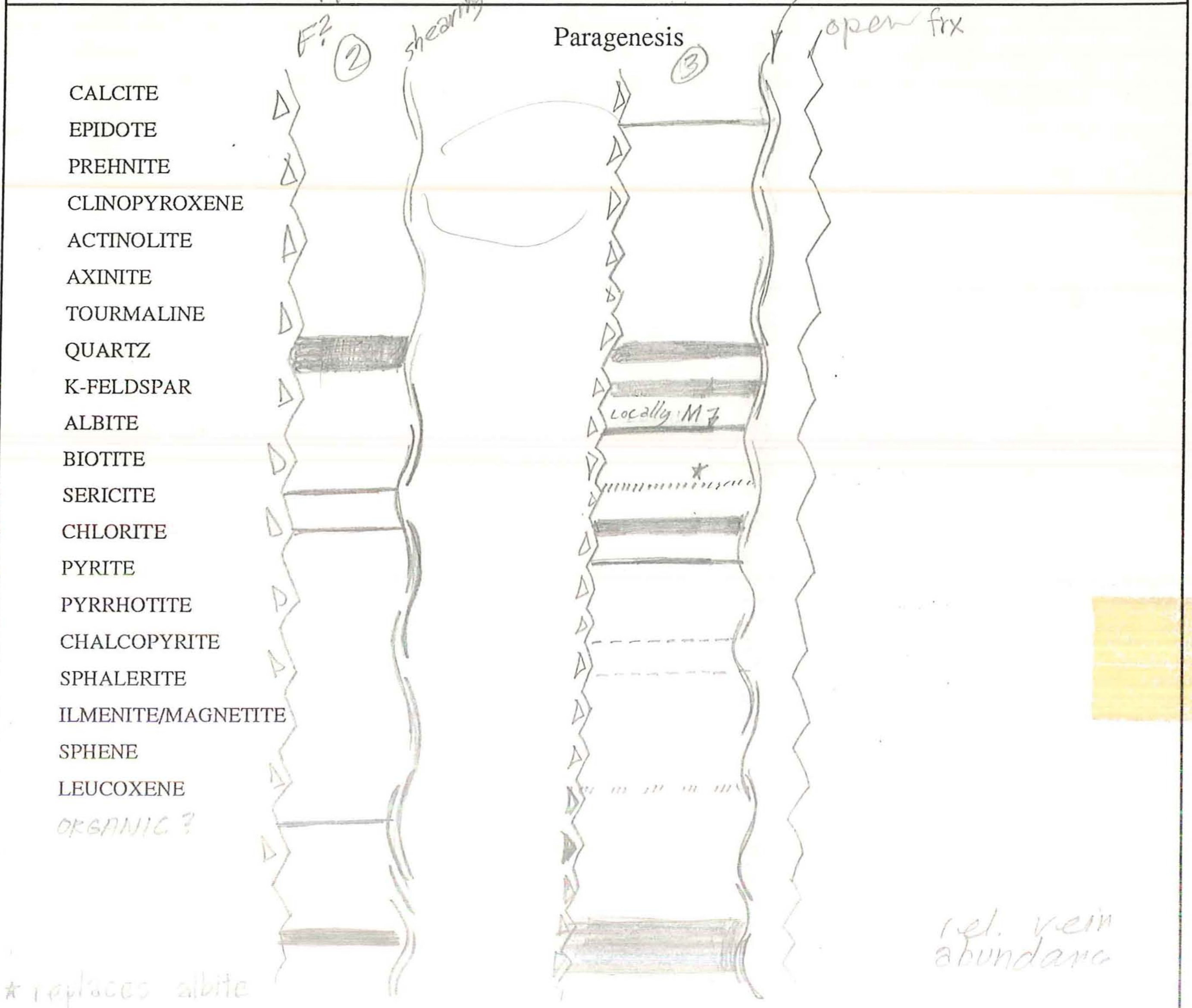
Alteration/Metamorphism L. greenschist met. / shearing of argill MGW

Fluid Inclusions (3) BELOW: ABUNDANT IN QTZ, <1-10μ DIA., MANY HAVE LEAKED, MOST VAP.-DOM. BUT CAN FIND GOOD ONES W/LIQ: VAP ≈ 4/1 looks like boiling

(3) abund in qtz, <1-10μ many leaked, but can find good ones L/V ≈ 4.5/1 — mostly vapor-dom.

Porosity Summary overall < 0.5% veins are tight — bulk of φ in late frx & rare φ in layer silicate aggregates.

Paragenesis



* replaces albite

‡ (1) looks very brecciated (jig/saw) clasts in quartz suspect originally a siliceous iron fm or iron-rich chert. these "veins" appear actually to be v. elongated lenticles.

RECONNAISSANCE NOTES

GRAPHIC LOGS

DEPTH | ALTERATION (WMS, WMS, PISS. EP, WMS, WMS) | FRACTURING (WMS) | VEINING & VUG-FILLING (WMS) | VEINLET & VUG-FILLING PHASES (QTZ, KFSP, EP, TOUR, PY) | GRAPHIC GEOLOGY | NOTES, COMMENTS | DESCRIPTIONS

8062

8062-8066.2 LITHIC METAGRAYWACKE, f-m. gr med-dk. greenish-gray, apparently massive; heavily veined — est n 7% of TRV; veinlets of several different ages: ? ✓ THIN-SECTIONS

① Tourmaline-rich: (± QTZ, KF?); 1-2% irregular, sheared; appearing, dark brownish-gray (—) <1 mm. wide.; mostly dip avg. > 70°

8063

(E) ?

② QTZ-EPIDOTE — (KF?) ±? (✓ SER, ACT.) 3-5%, seemingly random orientation, but 2 preferred — dips ≈ 30° & dips > 70°; these are generally ≥0.5-6 mm. in. dia, pinch & swell along strike (avg n 1 mm); larger vnlts. have occ. irreg. vugs up to 3 mm. dia., into which euh., prismatic qtz. xls. project.; some of these vugs could be filled with WAIRAKITE (??) in part.

8064

(F)

HYDROTH BXS.

8065

some 10X 3 X-sect

③ QTZ ± ep: opaque white w/thin epidote selvages; <1-3.5 mm. wide; <1% of TRV; dip > 70°

8066

GDHS-7A

core cut by numerous fractures perpendicular to core axis — these X-cut everything incl. all veinlets — avg. n 2 cm. apart — no shearing — really suspect these are drilling-induced in some fashion

8067

hyd. breccia

(NOTE) Many of the QTZ-VNS, (②) above) esp. larger ones, have folded, ptygmatic appearance — could be rexld., re-mineralized franciscan-age.

8068

TECTONICALLY INTERMIXED RNS & ARGILLITE

HYP. BX AT GRW CONTACT.

• Beginning @ 8068.9': intensely hydrothermally brecciated and stockwork-fractured, w/ open, crystal-lined vugs up to 5X5 mm. in X-section: ϕ increases to 2-4%.

ARGILL. GW

8069

GDHS-7D

MOST VNLTS DIP ABT. 65-85° BUT ALL ARE REPRESENTED

② GDHS-7A, ABOVE: app. same vein sequence as shown above; it's the later QTZ-KF-EP vnlts w/ ep. selvages which host the vugs.

8070

GW

• Below 8066 — same tendency for bimodal fracture/vein distribution. > 70° & < 30° dips. MOST OF THE THICKER VEINS & THOSE WHICH ARE VUGGIEST TEND TO BE STEEPLY-DIPPING.

8071

hyd. bx

• Stage ③ cemented hydrothermal breccia w/ qtz-ksp-lined vugs up to 3 mm. dia.

8072

72.14

GDHS 7F

DRILL HOLE GDHS-7

LOCATION

LOGGED BY J. HULEN 10/02/90

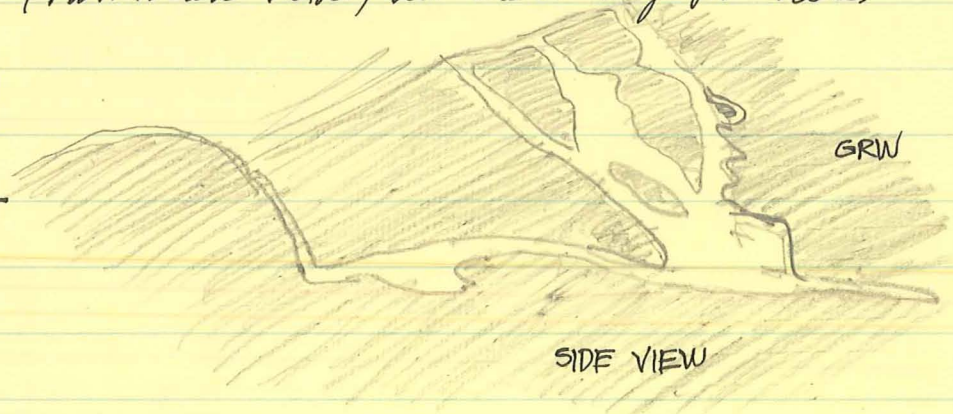
RECONN. NOTES (GPHS-7) JBH 10/02/90

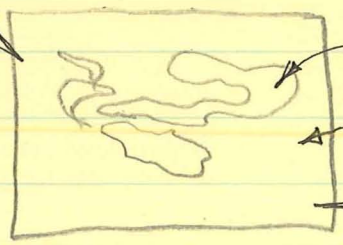
(#1)

Highly irregular, discontinuous.

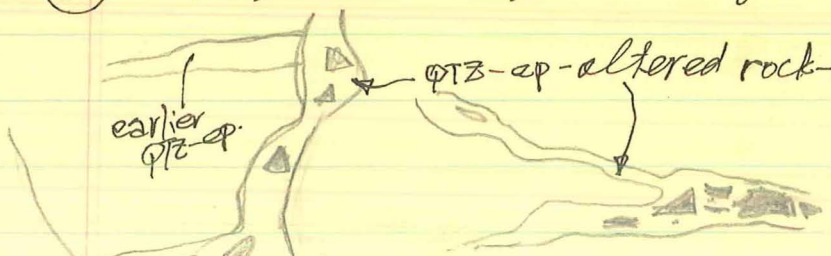
~ 8063.6': NOTE: Many of the ep.-qtz. vns. are v. complex, unusual-looking, compound, up to 12 mm. wide. — The edges of (and projections from) these frequently look almost folded — it's possible these represent refractured & mineralized (ptygmatically folded?) Franciscan veins, but can't say for sure.

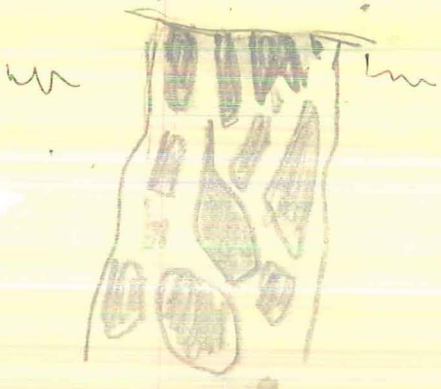
~ 8064.0 (XI)





(#2) complexly veined & hydrothermally brecciated rock (hnfls. MGW)





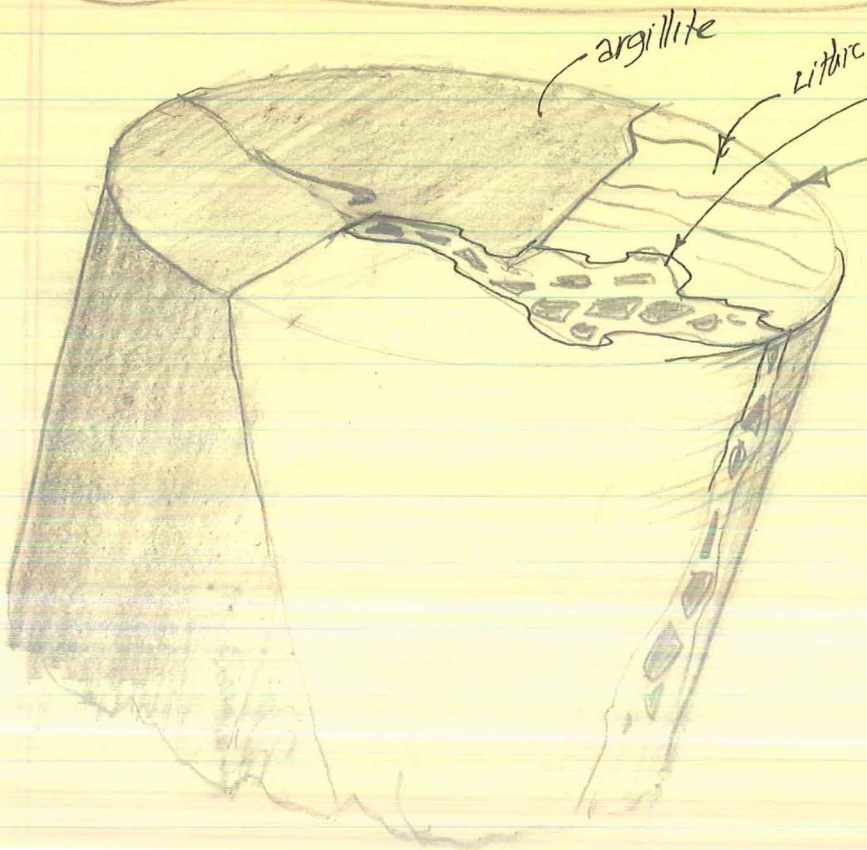
RECONN. NOTES

GDH5-7
JBH 10/02/90

8066.2–8068.8' argillite to phyllite, sandy, med.–dk. brownish-gray: notable decline in vein intensity from the overlying graywacke. Still appear to be the 2 generations of epidote-bearing veinlets, but the last of the two, dom. by quartz (± Kfsp?) w/minor epidote, is predominant tourm. may be present, but if so is diff. to see in dark matrix —— most veins are fairly high-∠ (>60–85°), but all ∠'s are represented

- some of the stage (3) vnlts coalesce to form qtz-kfsp± ep± suff.-cemented hydrothermal breccias w/ great jigsaw-puzzle textures.

(*3)

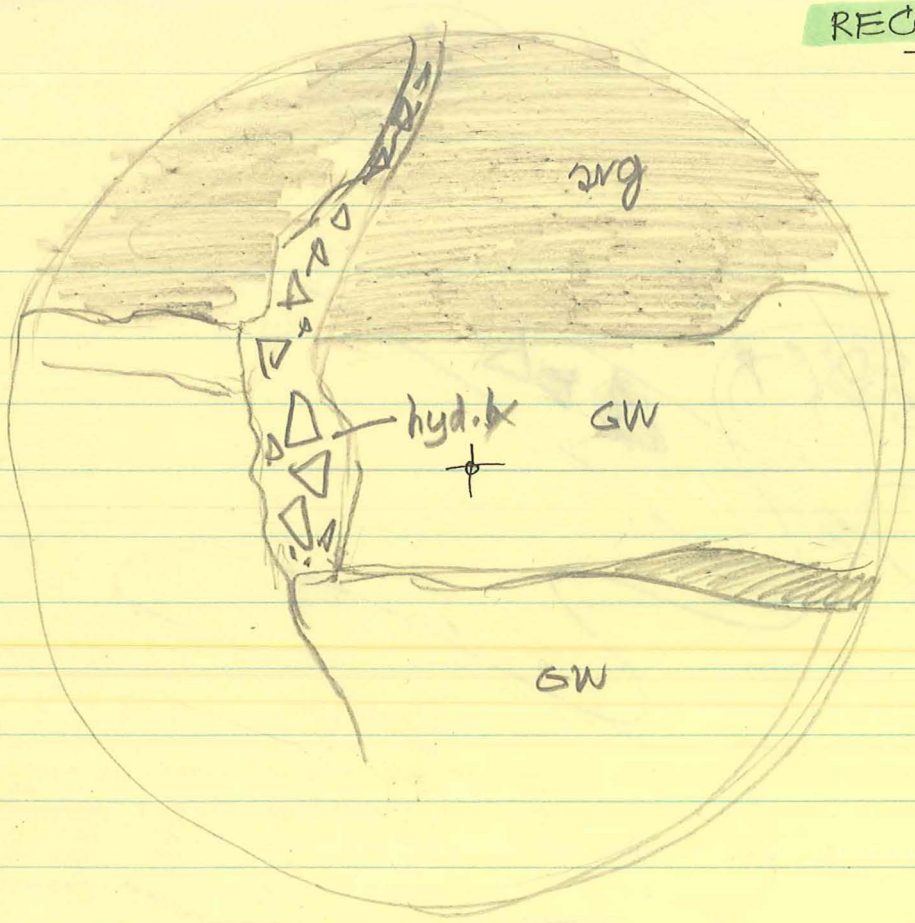


* note control on hydrothermal brecciation

RECONN. NOTES

GDH5-7 JBH 10/02/90

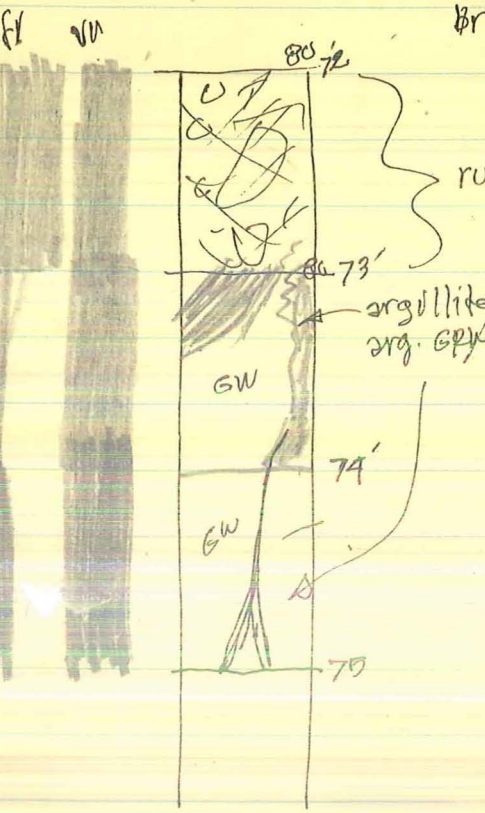
8868.6'



8868.8' – argillaceous VFG GRW, stockwk fractured/veined w/local hydroth. bx where several veins coalesce.
est n 5% TL vein mineralization.

NN. paragenesis is the same

- appears to be some movement on arg. after veining, but concentration of vns. in graywacke rel. to argillite is largely a function of relative brittleness.



rubble – numerous pieces <1–10 cm – mixed arg. GW & GW veining & paragenesis as above.

Calculation Record

UNOCAL 76

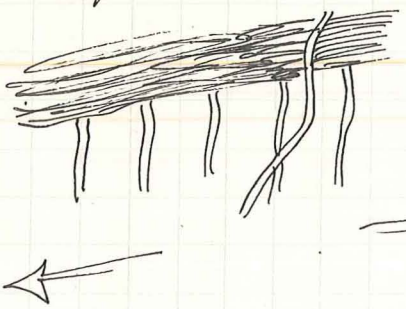
RECONN. NOTES

PREPARED BY	CHECKED BY	DATE	PAGE
J. HULEN		10/02/90	OF

SUBJECT	W.O./A.F.E. NO

IMPRESSIONS —— GDHS-7

— Definitely differential susceptibility to fracturing depending on rock type — the more argillaceous, the ~~more~~ fewer fractures.



in some cases, the GRW has been pulled apart, like so: the adjacent argillite has taken up the stress by shearing. later qtz-KF-Ep. veinlets, however, pass through both the earlier-veined GRW as well as the argillite:

— most hydrothermal bx dikelets/veinlets dip at steep angles (>70°) to core axis. bx veinlets are deflected at GRW/argillite contacts & are generally much thicker in the GRW

— Both stage (2) and stage (3) ep-qtz-kfsp veinlets can be vuggy — all vugs are lined w/ euhedral qtz + calcite crystals.

✦ some vugs really do look like dissalution features.

RECONN. NOTES

Calculation Record

UNOCAL 76

GDHS-7

PREPARED BY	CHECKED BY	DATE	PAGE
JH		10/02/90	OF

SUBJECT: X 0.6-0.7 — W.O./A.F.E. NO:

sheared crenulated - appearing contact.

stage (2) qtz - epidote veinlets truncated at contact with argillite in some cases it really does appear that there was some shearing along that contact after veining — in other cases, the veins just seem to die at the contact

PHOTO OPPORTUNITY !

complexly kinked — fractured m. gr. lithic M&W >2 vns/cm

vug

this one really does look like a dissolution feature.

8074

RECONNAISSANCE NOTES

Sample Identification	Petrographer/Date of Examination
DX-84-D-h	JEFF HULEN 09/26/90

Rock Type silty, ~~v~~ argillaceous, v.f-med-gr Lithic Metagraywacke

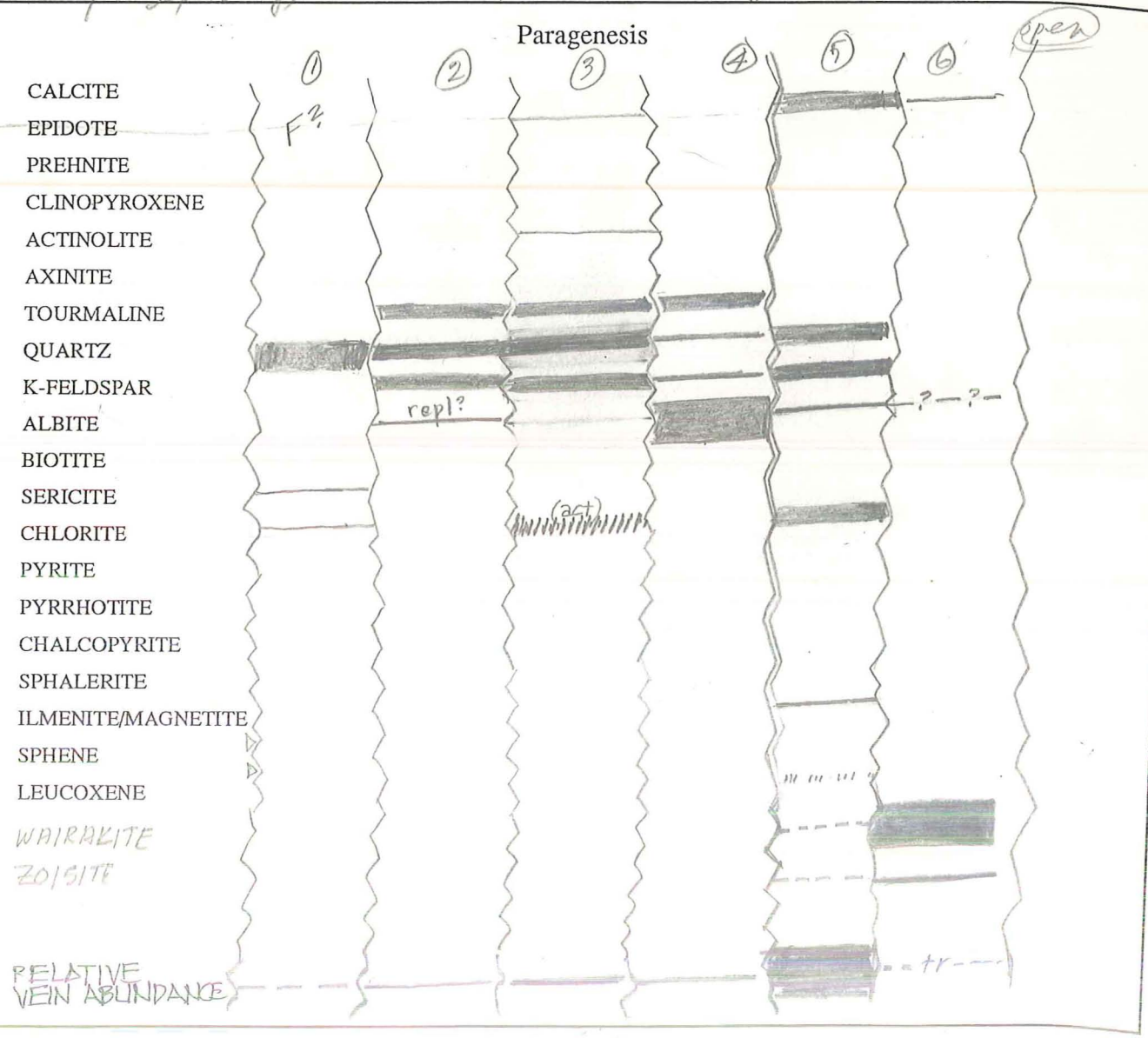
Fracturing/Brecciation/Veining and Vug-Filling crudely orthogonal vnlt sets w/ 2 other, minor sets oblique to these. vnlts account for 5-6% of rock. late open frx, both x-cut & follow vnlts.

Alteration/Metamorphism Greenschist metamorphism; poss incip. contact metamorphism with development of brownish phengite at expense of chl + ill. chlitz of detrital biotite; sparsely disseminated anh. tourmaline!
↳ subh. in 3% diss v. f. x/n. ilm ± leucoxene. (tr. chl plag.)

Fluid Inclusions
① mostly tiny (<<1μ), densely packed, appear to be dom. vapor-rich
②<<1-10μ; abund; dom. vap-rich; rare liq.-rich w/ L:V = 2.5-3/1
③ ④ as above v. abund. in albite

Porosity Summary; Apparent dissolution ϕ in selvage adjacent to silicic selvage on stage 5 veinlets — spongy-appearing 1-1.5 mm. wide. Albite in stage 4 vnlts. good vporosity;
<1-25μ; mostly vap-rich some liq.-rich 20μ w/ L:V ≥ 3/1 (much necking)

Paragenesis

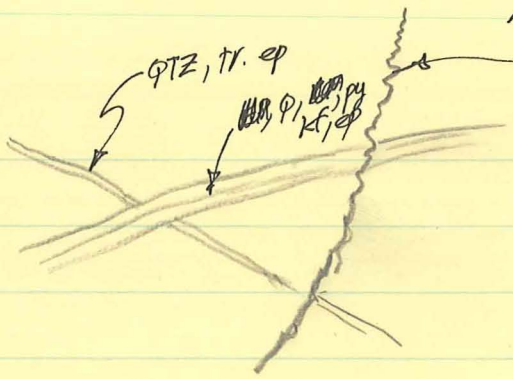


RECONNAISSANCE NOTES

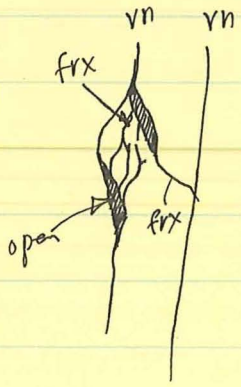
DX-84 JBH
10/01/90

REFER TO GRAPHIC LOG. (NOTES LEFT COLUMN)

*1



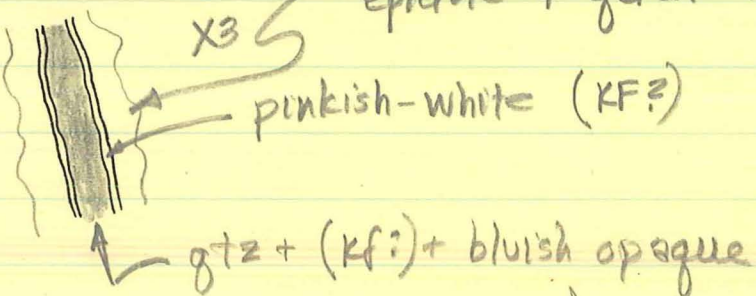
*2



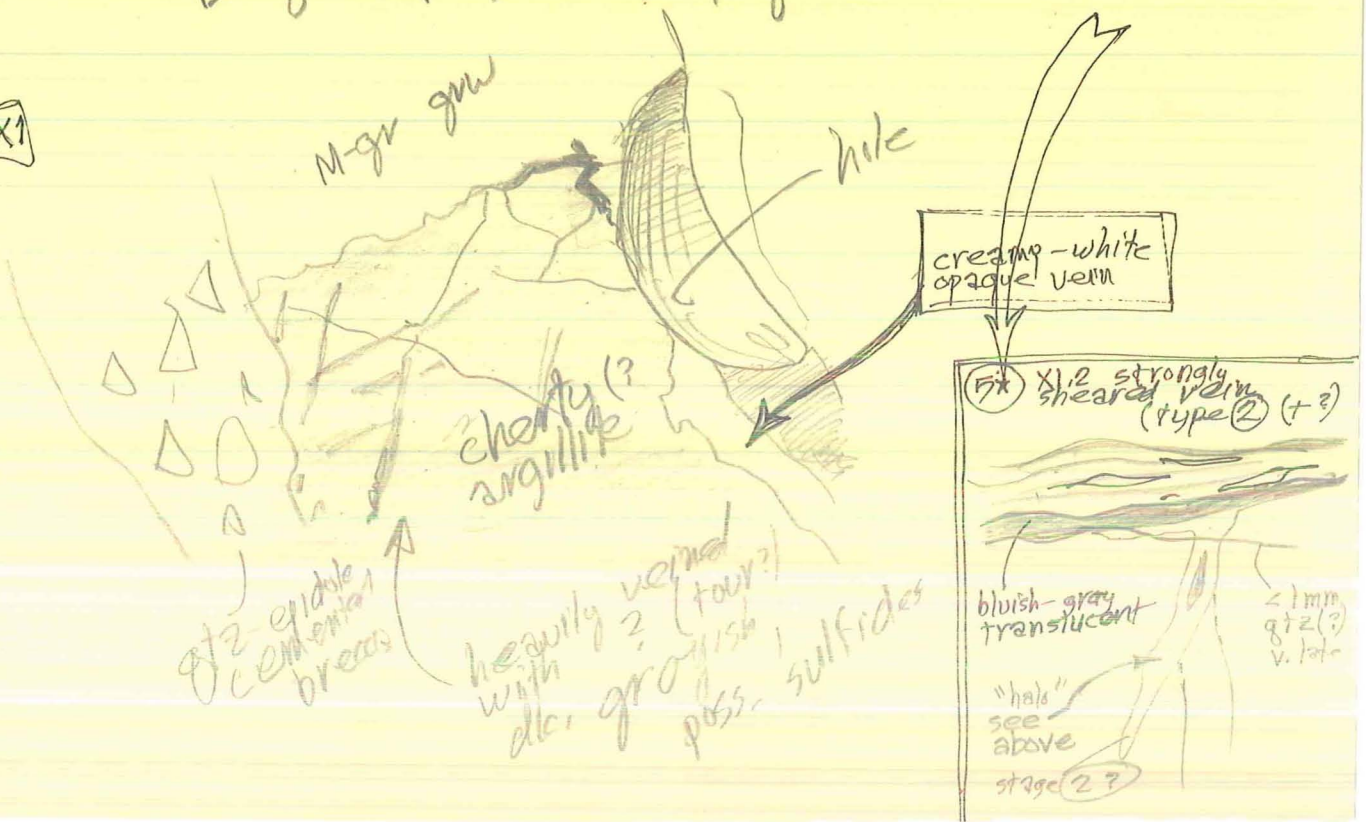
X1 Looking down core axis — late movement on older veinlets (four) appears to have created minor ϕ

POST-DATES TOURMALINE VNS.

*3



*4 X1



RECONNAISSANCE NOTES

BADLY BROKEN-UP, W/ JUMBLED PIECES.

late open fx < 0.1 - 1 mm, like this

DEPTH	GRAPHIC LOGS: ALTERATION (SIL. WMS, WMS; BLEACH/VEIN/SER. WMS; WMS, WMS)	FRACTURING WMS	VEINING & VUG-FILLING WMS	VEINLET & VUG-FILLING PHASES (QTZ, LF; EPID.; TOURM.; CALCITE; "WAIR"; PY; PO)	GRAPHIC GEOLOGY	NOTES, COMMENTS	DESCRIPTIONS ↳ doesn't look coring-induced
7730						2 vn. dips: ∠ 25° & > 75°	silty, arg., v.f.-m gr. Lithic metagraywacke, dense, med-dk. greenish gray, mod. veined; a few ① dark brn-bluish tourm-qtz-kf vnlts cut by more abund. ② EP-QTZ-KF-CHL vnlts:
7731						A-125-1 wrong? "F"?	– stage ① vnlts < 0.5 mm., irreg., disc.
						down, sp. vnlt dip 75° (3-4 vnlts/mm)	– stage ② " < 0.1-3 mm., w/ prominent bleached zones up to 4× veinlet width — these pinch & swell & are locally vuggy like this.
7732						another stage ② vein dip 35°	the vugs appear to be interstitial primarily to late-stage qtz — some of the ② vnlts appear to be sheared, but they don't offset earlier tourm. vnlts more than a few mm.
						" B-125-2 "	rel. proportions of the various vein minerals vary along strike of vein
7733						LATE FRAC. DIP 86°	• NOTE: early ① vnlts are ragged, appear "soaked" into matrix
						TOUR VN DIP 80°	• NOTE: stage ② vnlts. are commonly prominently banded. (epithermal appearance
						FRX FOLLOW OLD T-veins	NOTE! Most of the ** ① Tourm.-bearing veins are at high ∠s to core axis (dips of > 75°)
7734						TV dip 86°	• at least 2 episodes of stage ② veining.
						completely silicified (leached) argillite	• CORE BREAKS ALONG BOTH STAGE ① & STAGE ② VEINLETS.
7735						RUBBLE	• stage ② veinlets commonly form compound veinlets w/ stage ① veinlets (re-opening.
7736							
7737							7737–7738': Lithic MGW v.f.-f. gr. as above; RUBBLIZED pcs. are bound by fractures which mostly ∥ older veinlets
						Rubble.	avg. pc. of rubble is ≈ 5×3×2 cm.
						" "	a few of the fracture surfaces bounding these pcs. are coated w/ scabs of soft white mineral not calcite
7738						" E?	is this WAIRAKITE? note v. intense early tourmaline veing.
							• "WAIR" vnlts. < 0.7 mm. wide, banded seem to have translucent centers.
						Rubble	
7739							
7739.5						-	Rubble, as above; 5½" cored (internally)
						"	pc. @ 7739.5' has strongly sheared composite vein (see illus.) dip ≈ 60°
							• NOTE: 7740-41' (& perhaps a little higher) frac. surfaces in rubble sparsely coated w/ pearlescent, UKn. layer silicate (XRD for sericite.) avg. rubble pc. is ½ to 1.5 cm (< 0.1 – 4 cm) dia.
7741							

Volume-rubble pieces

2 pcs.

*1 *2 *3 *4 (5)*

✓ for SER.

DRILL HOLE DX-84

LOCATION

LOGGED BY J. HULEN

10/01/90
10/02/90

RECONNAISSANCE NOTES

GRAPHIC LOGS

DEPTH

ALTERATION — WMS | WMS | WMS | WMS | WMS

FRACTURING — WMS

VEINING & VUG-FILLING — WMS

VEINLET & VUG-FILLING PHASES — QTZ | CHL | PYRRH. | CPY

GRAPHIC GEOLOGY

NOTES, COMMENTS

(*3)

(*2)

(*1)

DESCRIPTIONS

schistose, argillaceous, LITHIC METAGRN (or) GRAYWACKE SEMI-SCHIST, v. prominently bedded, sheared // to bedding; alternating med. grayish-brown lenses/laminae & chloritic lenses/laminae; widely spaced creamy white siliceous laminae, sometimes slightly deformed/undulose; cut by chlor-qtz-pyrrhotite (latter rare) veinlets — most prominent is 1.5-7 mm. wide, w/ discontinuous milky quartz interior up to 3 mm. wide enclosed in chloritized rock flour up to 2 mm wide each side; qtz. locally contains clots of pyrrhotite, irreg. equant to elongate, ∠ 0.5-6 mm length or dia., w/ rare traces of cpy. The veinlets have selvages of bleached-appearing country rock up to 4 vein-widths wide (see note (*2)): the bedding/schistosity adjacent to the vein shows minor drag, and beds are displaced, so the host fracture is probably of tectonic origin; however, the chloritic rock-flour interior doesn't generally appear sheared, and may have been hydrothermally injected.

- Lowest pc (see SKETCH (*1)) has prominent lenticular, undulose-bordered chloritic siliceous layers (suspect chert)
- some older qtz. vns are plygmatically folded.

DRILL HOLE DV-1

LOCATION FOOTAGE NOT RECORDED ON BOX

LOGGED BY J. HULEN

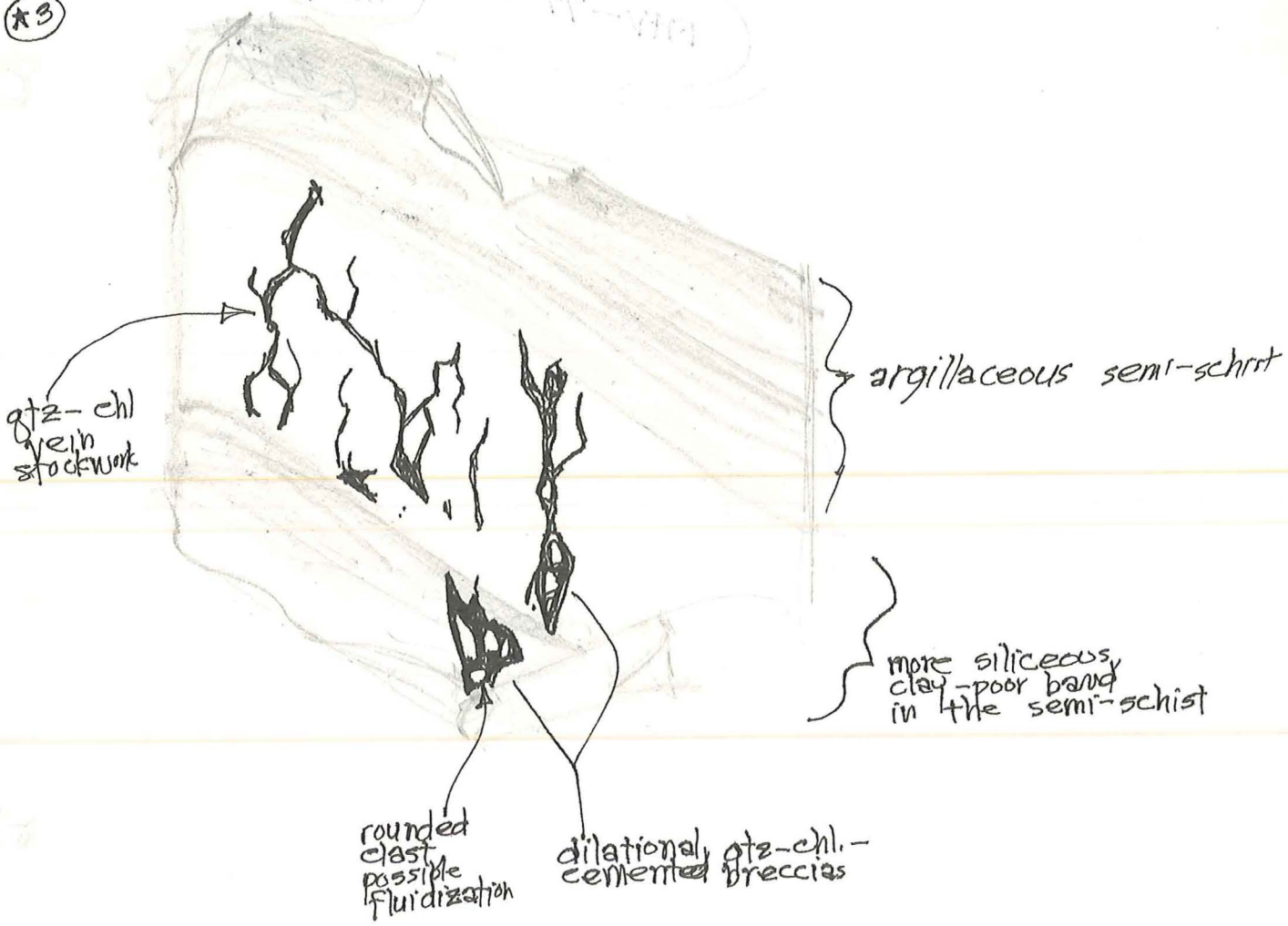
10/06/90

DV-1

RECONN. NOTES

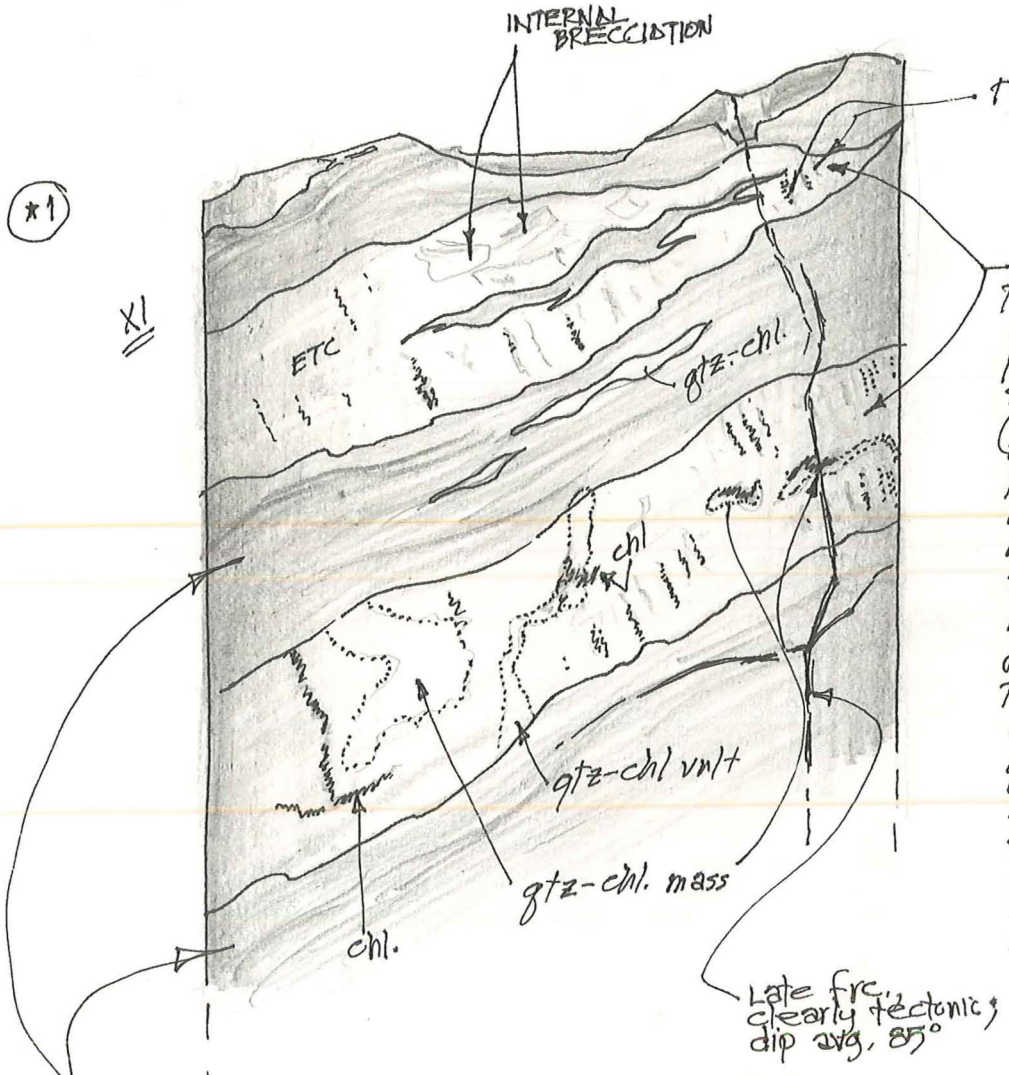
J. Hulen
10/06/90

#3



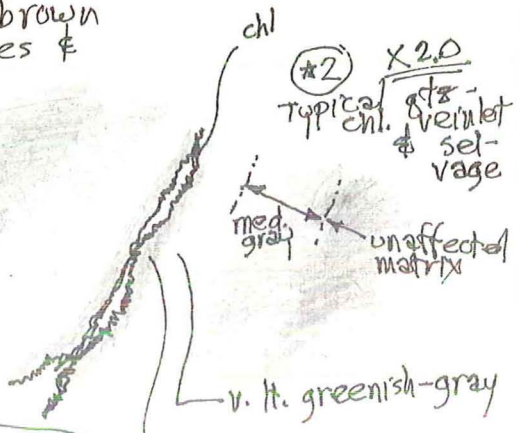
DV-1 — NO FOOTAGE RECORDED ON BOX

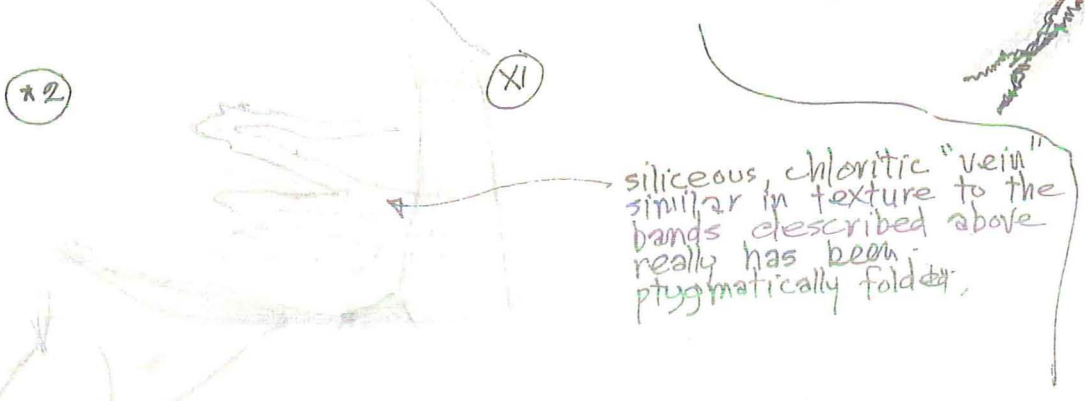
J. HULEN 10/06/90
RECONN. NOTES.



v. lt. greenish-gray to creamy white siliceous bands, probably chert; consist of uxln. silica (qtz) & chlorite; pronounced lenticularity and undulose margins; has been stretched, w/ development of ~~tet~~ tension frx ⊥ to bedding— these are now chlorite—qtz & qtz.; some internal brecciation & extensive recrystallization in vague amoeboid masses.

schistose, argillaceous, Lithic metagraywacke (or) graywacke semi-schist, medium brownish to greenish-gray, f-med. gr, laminae alternate irregularly with lenses & laminae rich in chlor. & qtz.





RECONNAISSANCE NOTES

Sample Identification	Petrographer/Date of Examination
DV-2-G	J. HULEN 09/22/90

Rock Type
altered, complexly-veined Quartz micromonzonite porphyry.

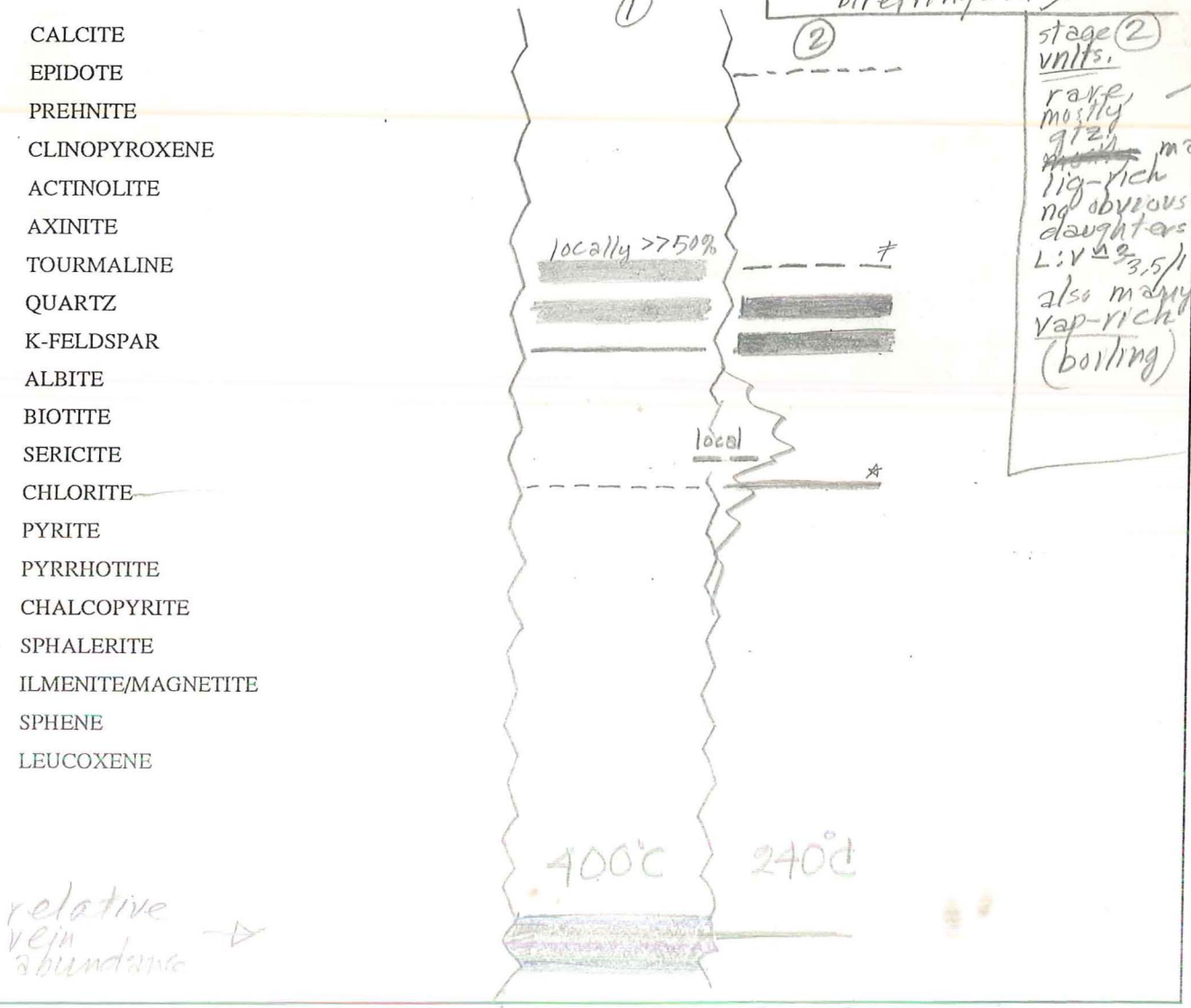
Fracturing/Brecciation/Veining and Vug-Filling
stockwork veining, random orientation vns, account for 7-9% of TRvol, <0.5–10 mm. wide — great blue & brown tourmaline.

Alteration/Metamorphism
diss, indiv. xls, xl. aggreg. & beautiful rosettes of tourmaline mod-locally intense sericitization of matrix & phenocryst fsps, esp. plagioclase. leucoxn/diss. ilm-enite

Fluid Inclusions
stage ① vnlts: qtz. contains numerous primary & 2nd liquid-rich incl. w/ L:V ≥ 2,5-3/1 (est Th >280°C) these commonly contain obvious daughter products, incl. isotropic cubic minerals, poss. dk. opaque microcrystals (these are porphyry Cu-style inclusions) HALITE SYLVITE
<1–20 μ
also a few unknown birefringent μxls.

Porosity Summary
est ≤ ϕ ≈ 2%, dom. as intercrystalline vugs in veinlets — also some μϕ in sericite & tourmaline (dchl) aggregates

Paragenesis



stage ② vnlts. rare, mostly qtz ± many lig-rich ng obvious daughters L:V ≥ 3,5/1 >250°C also many vap-rich (boiling) <1-5 μ

* H. gr cernish-brown, mod. birefr., aggregates as selvages
† poss. frags & xls. incorporated from earlier veinlets (encapsulated in quartz & Kfsp.

RECONNAISSANCE NOTES

GRAPHIC LOGS

DEPTH | ALTERATION (SER/PLAG, WMS | WMS | CHL/MAFIC, WMS | WMS | WMS) | FRACTURING (WMS) | VEINING & VUG-FILLING (WMS) | VEINLET & VUG-FILLING PHASES (QTZ, KFSP, CHL, PYRITE, EPIDOTE, TOURM.) | GRAPHIC GEOLOGY | NOTES, COMMENTS | DESCRIPTIONS

3708'

A — stage ① vns dip. domx 65°

qtz. latite ppy or qtz. monz. ppy; creamy lt. gray, porcellaneous-appearing ("QUARTZ PORPHYRY"); complexly veined; appear to be 2 stages: early ① TOURM-QTZ±KFSP± chl; then later ② QTZ-KFSP-CHL±EPIDOTE; stage ① veins are dk., sl. greenish-gray, v. irregular, both forming a randomly-oriented stkwk & a few larger veinlets at high ∠s to core axis — vnlts range from <0.5 mm to 10 mm. — actually most are oriented @ ≤ 25° to core axis pinch, swell, anastamose — many of the larger vnlts. are v. vuggy/porous, w/ euh. qtz. & KFSP xls. projecting into cavities — the ones that are open are zoned, w/ tourm.-rich margins & qtz±KFSP vuggy interiors; NOTE: ⊥ to core axis, veins define jigsaw puzzle breccias — NOTE ALSO: — along strike, many of these veins merge into vbreccias cemented w/ qtz-KFSP-chl-tourm. (vbx masses up to 25 X 150 mm. in X-sect.)

3709'

pc. B missing

3710'

C — ; SLIK ON CHL. VN.

D ★ — shearing along this veinlet.

3711'

E — 63-65° DIP

F

G

3712'

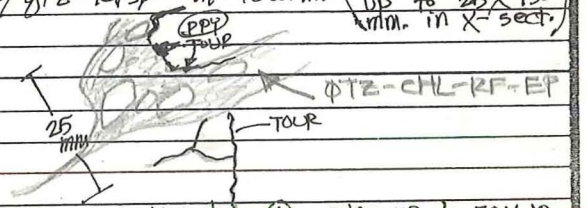
H

AVG. MAJOR VEIN DIP n 72°

3713'

MOST. VNS DIP 65-85°

I



3714'

HYDROTH. BRECCIAS

J

major bx. vein dip n 68°

3714.5'

NOTE: vugs in stage ① veins up to 50 X 10 mm. in X-section, commonly lenticular propped open w/ 2nd min'ls. LOOKS LIKE 'HYDRAULIC FRX NETWORK w/ local hydroth. bxs.

• STAGE ② vnlts. also open, poss. prom. "pinch & swell" — ∠0.15-10 mm. wide, only a tr. of tourmaline — also looks like chl. may have been deposited dor. fr. soln. (stage ① chl. may well have replaced actinolite.

ALTERATION: ① v. prominent bleached zones/selvages extending up to 3 vein thicknesses out from stage ① veinlets (√ THIN-SECTION). — where vnlts. are dense, entire host rock is bleached. — in these bleached zone, diss. tourmaline clots, irreg., up to 7 mm. in diameter. (ALSO: SEE DRAWING "B")

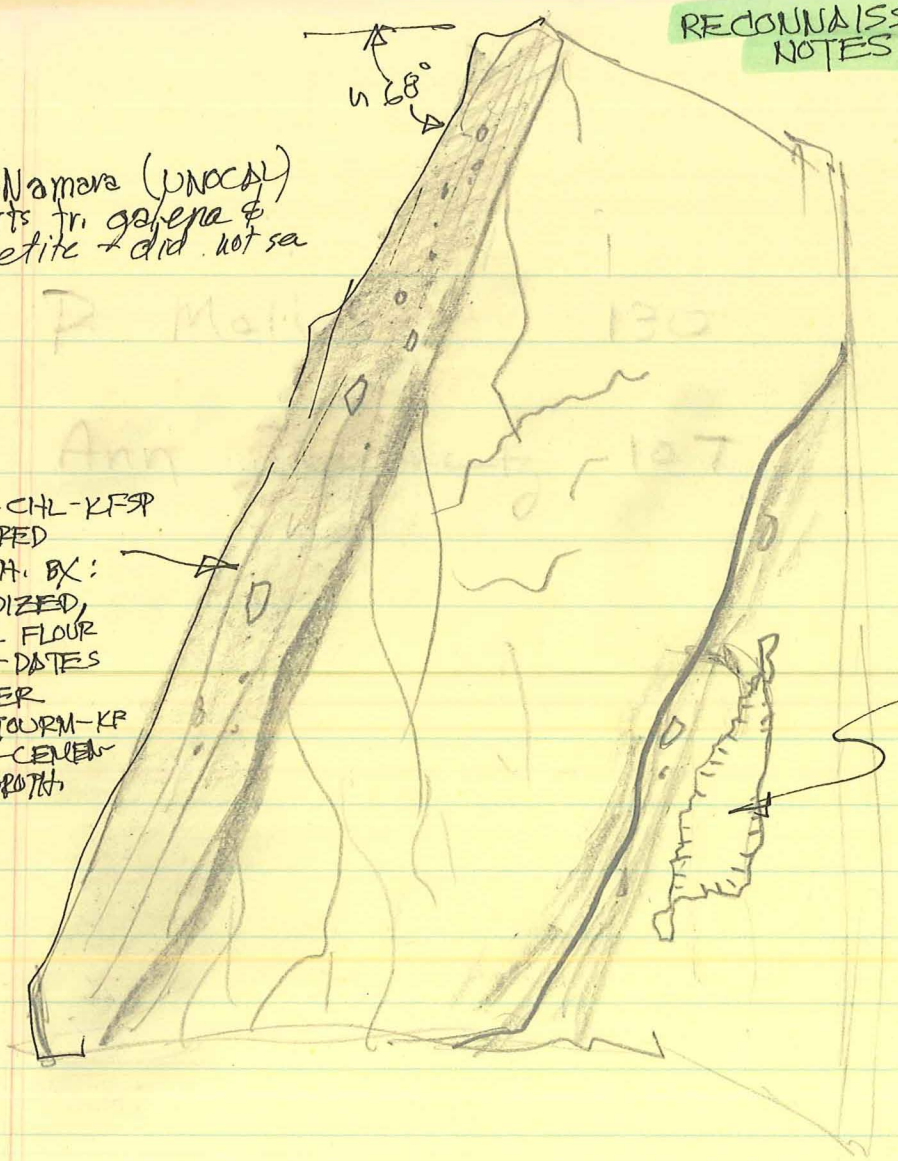
DRILL HOLE DV-2

LOCATION

LOGGED BY J. HULEN 10/01/90

RECONNAISSANCE NOTES (DV-2) JBH 10/01/90

pc. J

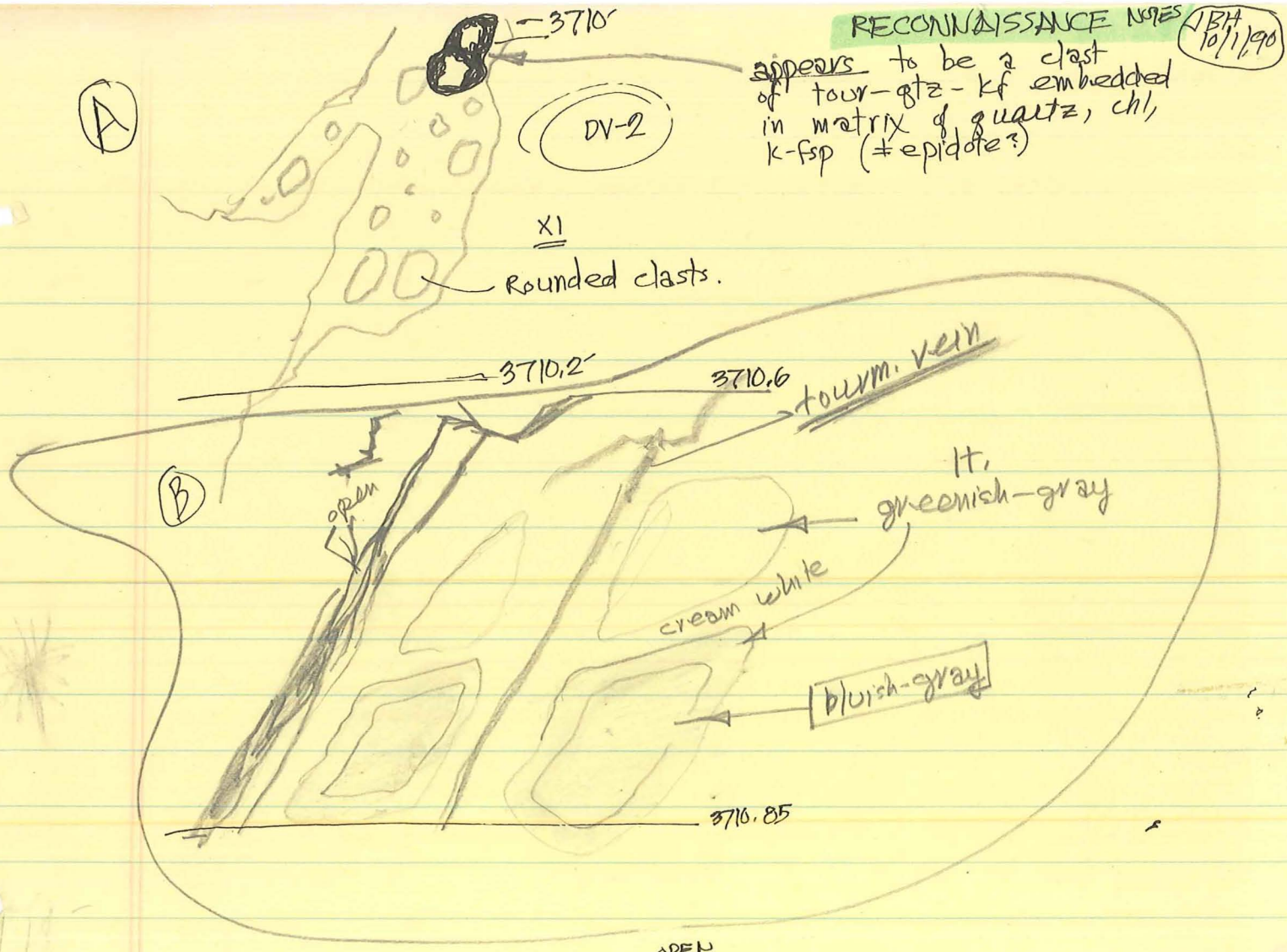


IMPRESSIONS:

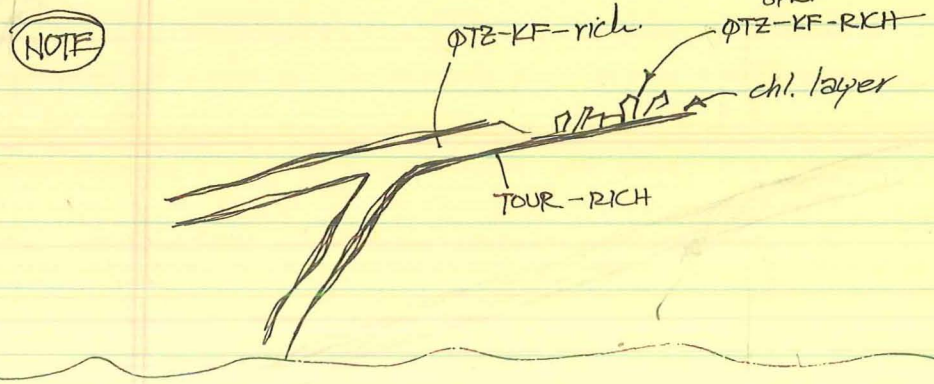
2 obvious vein-stages, each following episode of hydraulic fracturing & hydrothermal brecciation: The latest stage hydrofrac event was responsible for the open veins/vugs —— some earlier veins re-opened —— obvious fluidized & jigsaw-puzzle hydrothermal breccias: most fracs. fairly steeply-dipping

i.d. vein selvages (important)

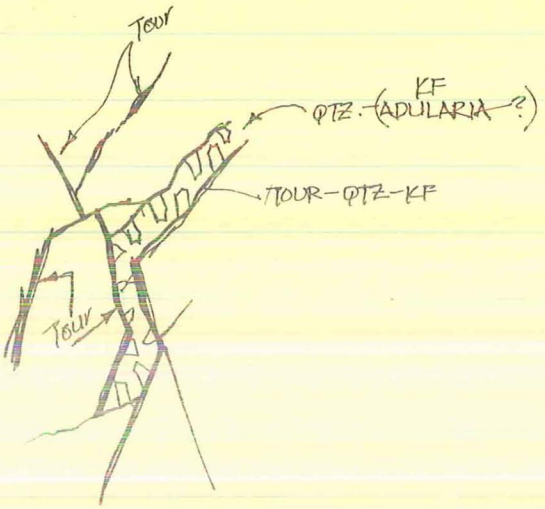
RECONNAISSANCE NOTES BH 10/1/90



appears to be a clast of tour-qtz-kf embedded in matrix of quartz, chl, K-fsp (± epidote?)



consider possibility that tourm.-rich veins have been re-opened, filled w/ stage ② veinlets.



PC-"H" — clear textural evidence that late chl-qtz-kf veinlets fill, in many cases, re-opened Tour.-rich veinlets

RECONNAISSANCE NOTES

Sample Identification	Petrographer/Date of Examination
GIC-21 5864.5B	J. HULEN 09/24/90

Rock Type: CPXN-BTE-HBL QTZ. MONZONITE PORPHYRY (poss 2 amphiboles — one like tremolite)

Fracturing/Brecciation/Veining and Vug-Filling
sparsely veined, <0.5% of TL rock volume
origin of frx unclear

Alteration/Metamorphism
hbl. repl. cpx
pervasive, sparsely diss. randomly-oriented actinolite needles
local clots of pneumatolytic, acicular tourmaline sprays ("sea urchins")

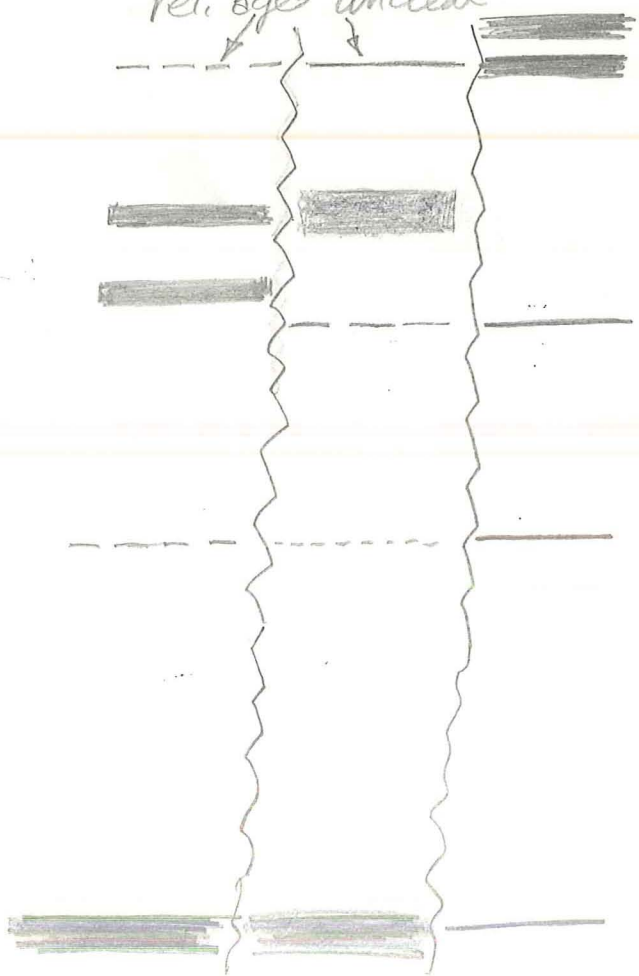
~~Fluid Inclusions~~
unknown, lath (rnded)-shaped, v. high-relief // ext., v. low biref. mineral.

Porosity Summary
< 0.3% (poss < 0.1%)

Paragenesis

rel. ages unclear

CALCITE
EPIDOTE
PREHNITE
CLINOPYROXENE
ACTINOLITE
AXINITE
TOURMALINE
QUARTZ
K-FELDSPAR
ALBITE
BIOTITE
SERICITE
CHLORITE
PYRITE
PYRRHOTITE
CHALCOPYRITE
SPHALERITE
ILMENITE/MAGNETITE
SPHENE
LEUCOXENE



RECONNAISSANCE NOTES

Sample Identification	Petrographer/Date of Examination
NEGU-17B Unocal/Geysers	Jeff Hulen 09/26/90

Rock Type: Lithic Metagraywacke, F-MGR

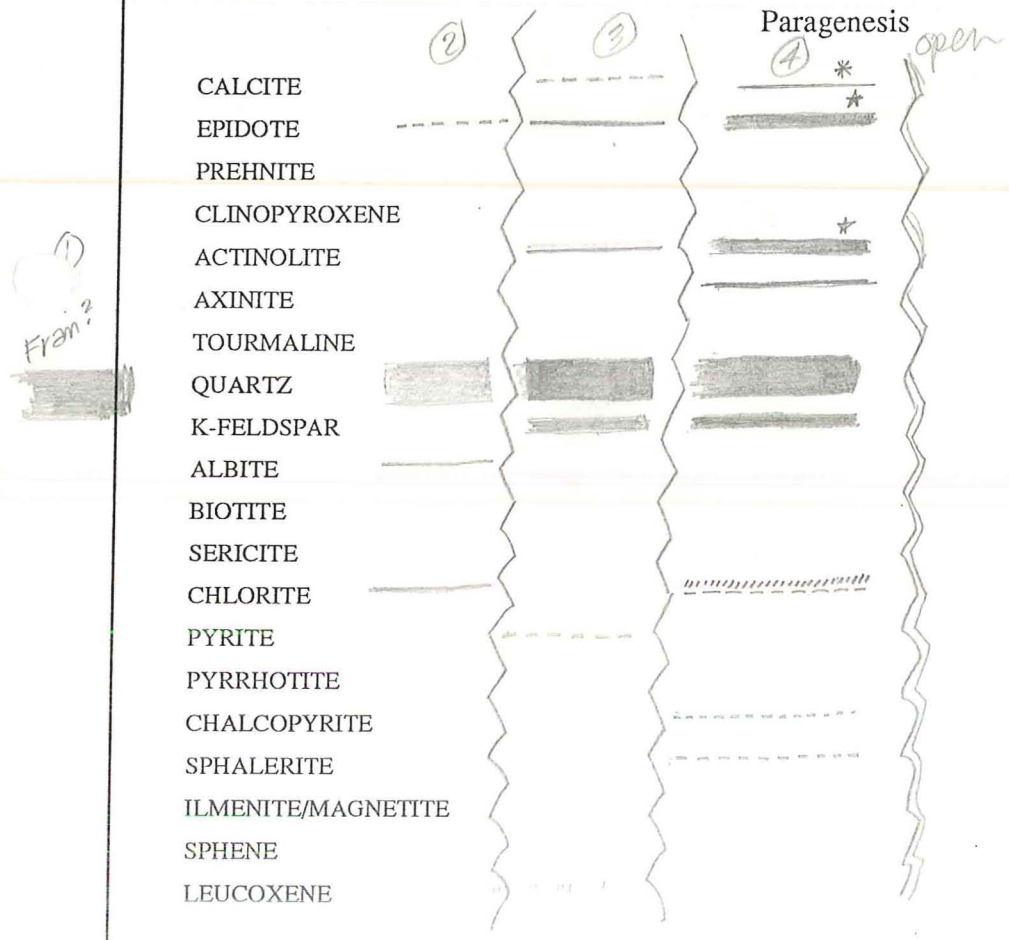
Fracturing/Brecciation/Veining and Vug-Filling: latest stage µfrx (< 0.5% of TRV) follows older vnlts
~3% vnlts plus fractures
open vugs in stage ④ veinlets below, interXn., up to 0.4 mm. dia

Alteration/Metamorphism
L. greenschist metamorphism
fsp – albite
matrix to chl-ser-rich aggregate
sp sparsely repl. albite (diss. anh. grains & grain aggregates)
poss. chltzn. of bte.

Fluid Inclusions
① avg. <µ; abund. all (3). v-rich
③ same as ④
④ <1–12µ; mostly vapor-rich; liq.-rich est Th ~280°C
est Th of primaries ~320°C

Porosity Summary
most ϕ in stage ④ vnlts.; minor ϕ (µϕ) in or in layer silicate-rich clasts
tr. vug ϕ in other vnlts. some ϕ in latest-stage µfrx (drill-induced.

Paragenesis



① Fram.?

* commonly encapsulated in axinite
* diss. shreds in qtz.-lost bte
qtz. replaced calcite

RECONNAISSANCE NOTES

Sample Identification L'esp 2C	Petrographer/Date of Examination J. Hulen 09/28/90

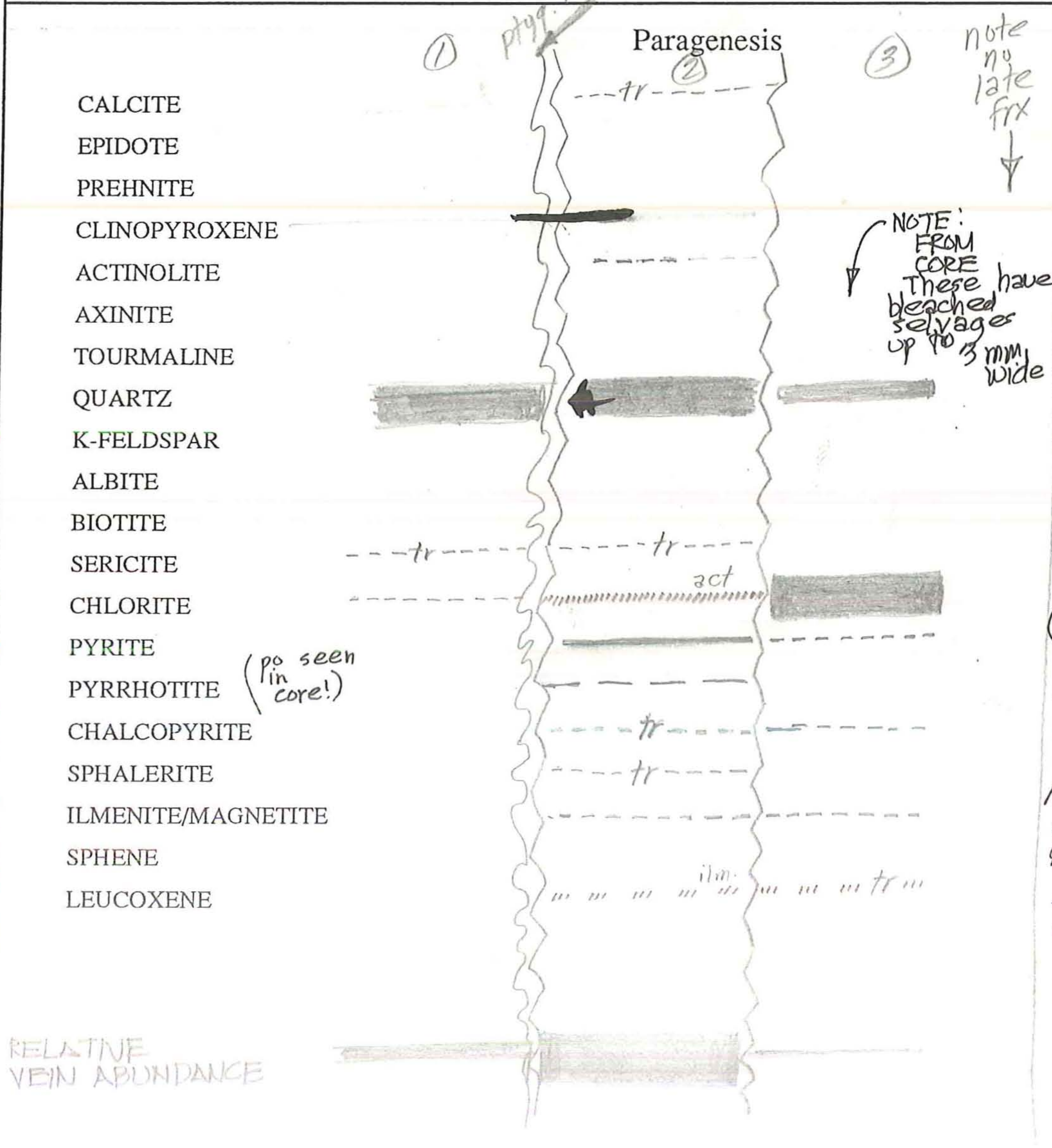
Rock Type Biotite-rich, hornfelsic, lithic METAGRAYWACKE w/ some ptygmatic folding of early veins (qtz - Franciscan ?)

Fracturing/Brecciation/Veining and Vug-Filling 3 stages of veining, as shown below no obvious shearing
stage (2) vns. <0.5-5 mm. wide, anast. & pinch & swell

Alteration/Metamorphism	Fluid Inclusions IT BOILED!
conversion of original illite-chl. matrix to lt. brown biotite (metamorphism): widespread silicification/ ~~sericitization~~ & chloritization of matrix (including biotite) as broad halos related to the veins selvages	(2) abund, <1-15μ; many primary, coexisting liq- & vap.- rich in growth zones (qtz) L/V in L-rich ≅ 2.5-3/1 uncountable secondaries mostly V-rich

(margin note:) poikilitic enclosure of qtz, chl actinol. in sulfide (py

Porosity Summary <0.3% TL φ - dom. as intercrystalline vugs in stage (2) veins



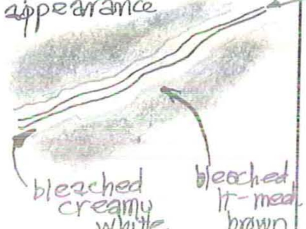
more vein info

quartz poikilotopically encloses small anh. patches of clinopyroxn.

chl. has relict radiating fibrous texture

(NOTE) IN ACTUAL CORE, THERE appears to be another generation of veinlets minor, but including QUARTZ & BTE

these have this appearance



RECONN. NOTES

Calculation Record

UNOCAL 76

PREPARED BY	CHECKED BY	DATE	PAGE
J. HULEN		10/02/90	OF

SUBJECT: L'ESP-2 11,051-@ 11,052.5'

W.O./A.F.E. NO:

NOTE: core from this interval is quite fragmentary so an actual log doesn't reaally seem appropriate.

ROCK is HORNFELSIC metagraywacke (f-med.-gr.) to (meta-)argillite, biotitic, med. to dark grayish-brown, v. dense w/ few open spaces.

Plug "A" from @ 11,051.4'
plug "C" from @ 11,051.7'
plug "B" not shown

"A" – veinlets account for @ 5-6% of TRV (locally up to 8% of (8 cm³ vol)

oldest to youngest

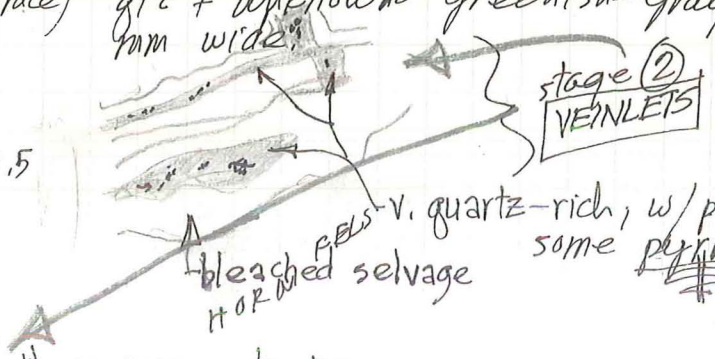
① quartz – highly irregular, lenticular & commonly ptygmatically folded; < 2 mm. width (<1%

no real preferred orientation

② quartz – (–tourm.?) (K-fld) ← ± PYRRHOTITE, PY (3-5%) bluish-gray to gray translucent, irregular, mostly discontinuous, gen < 1mm, but coalescing to form irregular masses up to at least 10 mm. in diameter

③ Highly irregular bleached-appearing selvages < 1.5 mm. wide (bte converted to sericite?)

④ (Trace) qtz + unknown greenish-gray mineral, < 0.5 mm wide?



LOCALLY — these are up to 10mm

RECONN. NOTES

Calculation Record

UNOCAL 76

PREPARED BY	CHECKED BY	DATE	PAGE
J. HULEN		10/03	OF

SUBJECT L'ESP-2 | W.O./A.F.E. NO.

late chl. veins not deformed

IMPRESSIONS

RX is hornfelsic, avg., lithic MGRW w/ minor argillite, v. bte-rich med-dk. grayish-brown moderately veined, w/ actual 2nd open-space-filling minerals accounting for 3-4% of total rock volume. — areas affected by the veining (incl. selvages) up to 12-15? % TRVol.; Early qtz. vns, vnlts commonly intricate ptyg. folding; Main stage ② of veining mostly qtz. w/ unknown translucent blue-gray minrl. ± minor sulfide, actinolite, chlorite, ilmenite? These stage ② veinlets <0.5-13 mm. wide (avg. in 1.5) pinch & swell noticeably along strike, v. irregular, tendency to be discontinuous → look very much like they were emplaced in somewhat plastic host rock, then deformed a bit after emplacement (minor folding, though not as intense as in early Franciscan veinlets; there are a few vugs in these stage ② veinlets — tend to be lenticular, up to 10X3 mm in X section (avg. < 3X1 mm); lined w/ euhedral qtz. (± other minerals?); also: many of the stage ② veinlets have a "braided", sheared appearance (again, post-emplacement deformation

POSS. REASON FOR BETTER ϕ IN GRW THAN IN CORRESPONDING HNFLS.:
HNFLS WAS PLASTIC WHEN VEINS WERE EMPLACED, OPEN-SPACE FORMATION INHIBITED ∴, MANY VUGS, IF FORMED, COLLAPSED WHEN VEINS FURTHER DEFORMED AGAIN AFTER VEIN EMPLACEMENT AS HOT PLASTIC

in GRW, brittle, vugs formed in veins remain open because no flowage of host-rock after

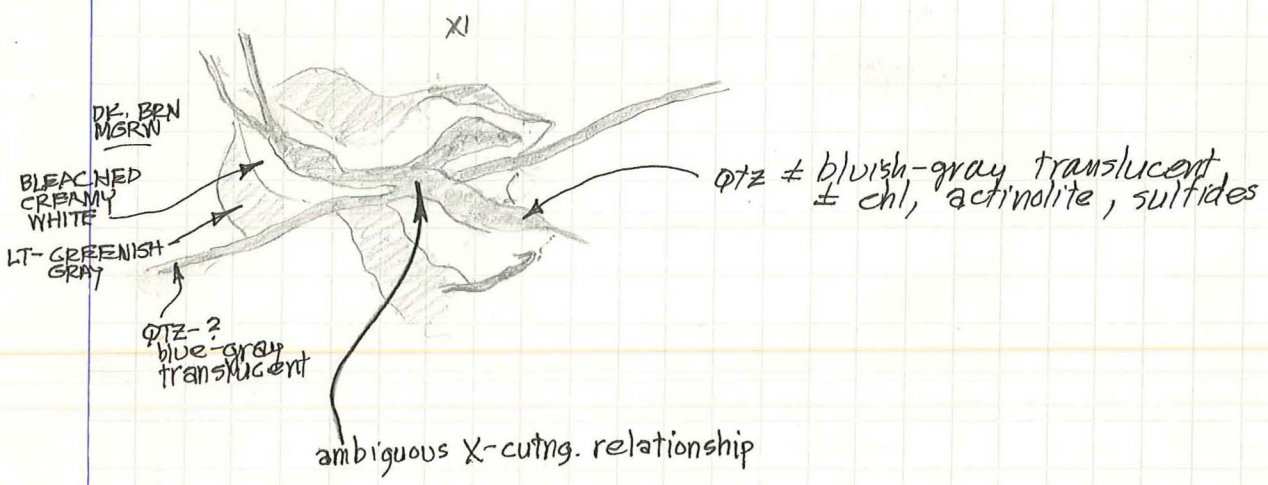
RECONN. NOTES

Calculation Record

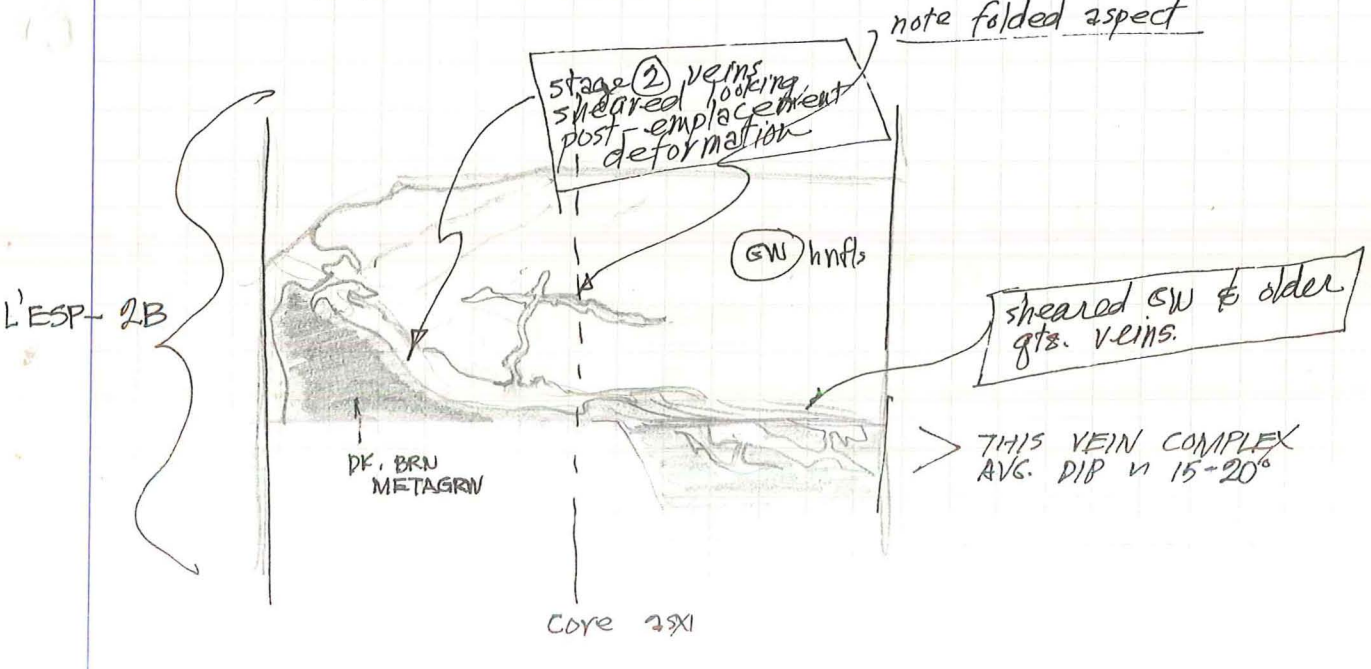
UNOCAL 76

PREPARED BY	CHECKED BY	DATE	PAGE
L'ESP-2 J. HULEN	✓ The big checker	10/03/90	OF

SUBJECT: L'ESP-2 | W.O./A.F.E. NO.:

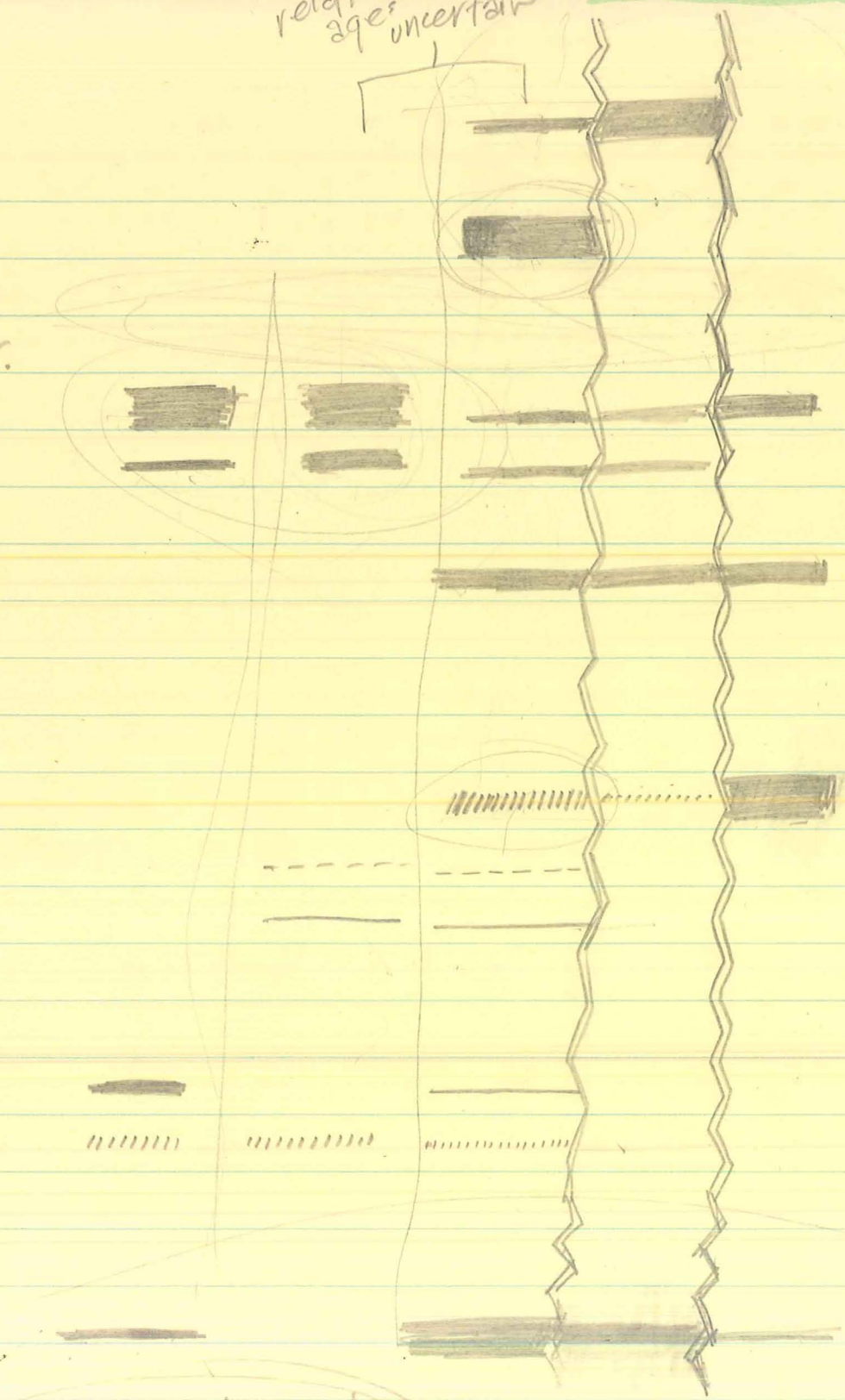


NOTE: ↑ VEIN RELATIONSHIPS FROM A MISCELLANEOUS PIECE ACTUAL DEPTH UNKNOWN



RECONN. NOTES

LF-48



RECONN. NOTES

GRAPHIC LOGS

DEPTH	ALTERATION (WMS WMS WMS WMS WMS)	FRACTURING (WMS)	VEINING & VUG-FILLING (WMS)	VEINLET & VUG-FILLING PHASES	GRAPHIC GEOLOGY	NOTES, COMMENTS	DESCRIPTIONS
8089 (K) (J) 8090 (L) 8095' 8096 96.5'						ST ② VNLTS DIP 40-45° ST ③ FeAx VULTS DIP OPPOSITE DIRECTION AT ~30-40° ← STAGE ① DIP 40-55° to 65° NO CORE VNLTS AVG 40-55° ← STAGE ② DIP AVG ~50° STAGE ① dip ~65°	8089-8090.06' → "FELSITE" ↙ "QUARTZ PORPHYRY"; probably quartz micro-monzonite porphyry; intensely veined w/ 2 or more generations of hydrothermal minerals; Rock is lt. gray, but extensively bleached creamy white in selvages adjacent to veinlets; 3-4% diss. mafics, lath-shaped to irreg., <0.5-4 mm. diameter, bte in part, hbl. in part, but apparently extensively altered to chlorite (+?); 7-10% "quartz eyes"; 2-3 mm. avg. diameter commonly rounded; ~10-12% fsp phenos, subh-euh., slightly larger than qtz.; sugary-appearing groundmass. (pxlite). VEINLETS account for ~5% of the rock — with associated selvages, they take up at least 20% of the rock; from oldest to youngest, they are: ① quartz ± chl ± ilmenite (?) ± ? ← ✓ T.S ~1% of TRV; (V.) vague borders, commonly w/ micro-"sheeted" appearance locally — sort of a "soaked" look (devitric?) up to 10 mm. wide Poss. tourm. ② CHL-QTZ-EP (+?) poss ± FeAx; ✓ T.S irreg., discontinuous, <0.1-2 (avg 0.5) mm. wide; dk. greenish overall; irregular selvages extend out into groundmass up to 4 mm; selvages are bleached, creamy white; 2-2.5% of TRV ③ FeAx-Ep-Qtz ± Ch; distinctive translucent smoky pink color; up to 2.5 mm. wide (avg. ~1 mm.) selvages same as above, but extend out into matrix up to 10 mm. 8090.06-8090.5: NO CORE BETWEEN 8090.5 & 8095': "QUARTZ porphyry", as above, but apparently more phenocryst-rich & less altered/veined 10-12% qtz. & ~15-17% FSP VEINLETS account for ~3% of TRV: ② ⊗ CHL ± qtz, tr. py & po, avg. <0.3 mm up to 1 mm. wide, dk. gray-green, could include act. &/or tourmaline. —form en echelon belts up to 10 mm. wide (NO) ⇒ "belts" are disrupted stage ① veinlets as above retrx, then mineralized w/ stage ② vnlts.

DRILL HOLE LF-48

LOCATION

LOGGED BY J. HULEN

10/02/99

Calculation Record

RECONN. NOTES

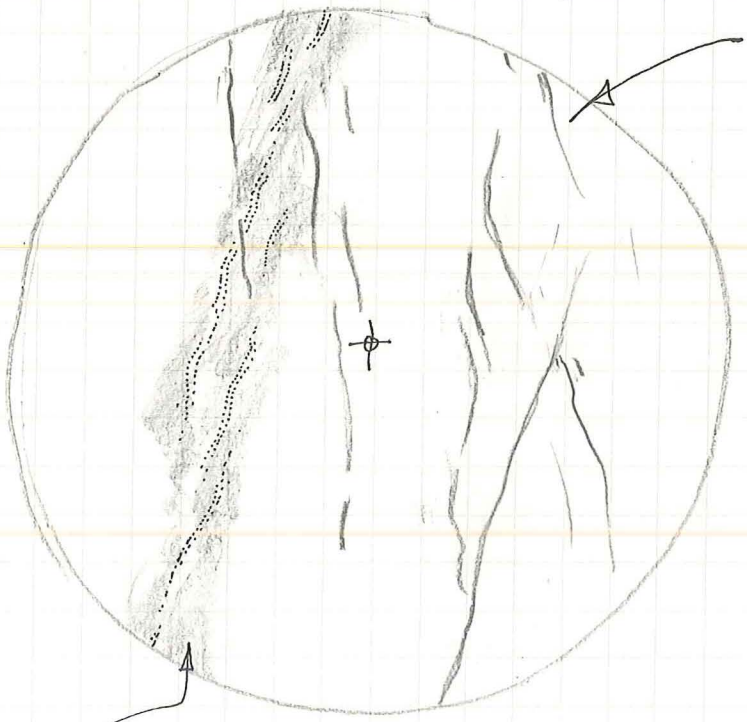
UNOCAL 76

PREPARED BY	CHECKED BY	DATE	PAGE
JBH		10/02/90	OF

SUBJECT: LF-48 additional notes

W.O./A.F.E. NO.:

"①" 8095 - 8095.3' : Basically same as piece ①



8095.3 - 8096.4':

8095.6 → as above

8095.6 - 8096.4' → as above but w/ xenolith of BTE-HBL GRANODIORITE, f-m.x/u. w/ 30% mafics, chltzd., in irreg. to lath-type aggregates of size = 3-7 mm.

stage ② veinlets as described above but have densely sheeted aspect w/ < 10 mm. commonly between veinlets.

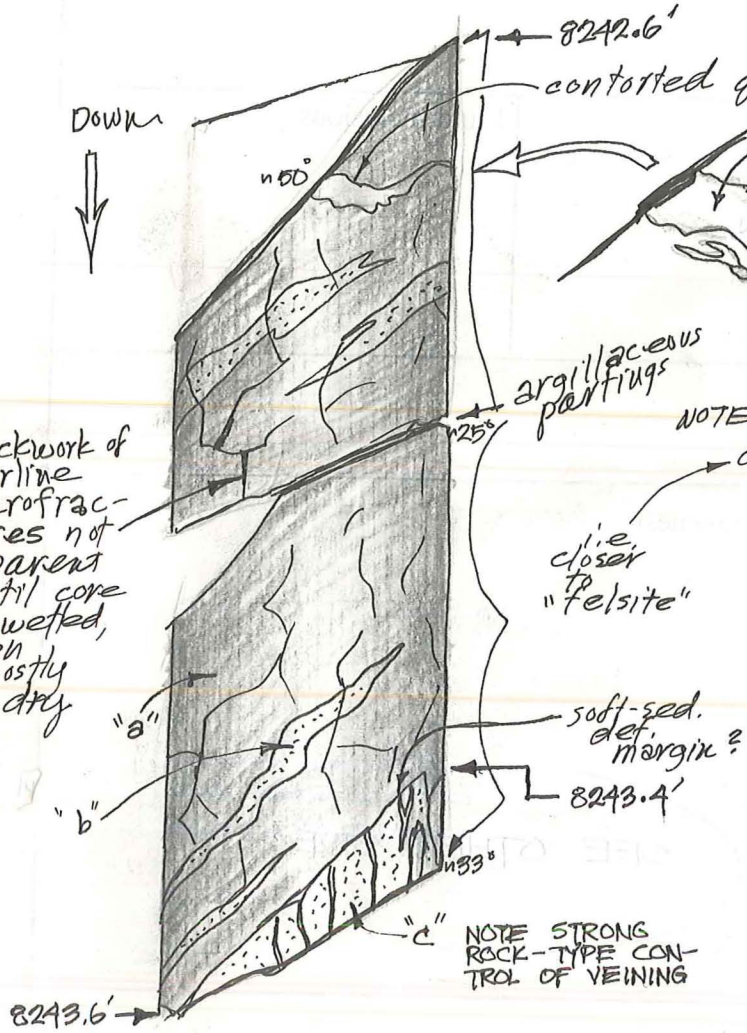
stage ③ veinlets are relatively rare, but some are large!

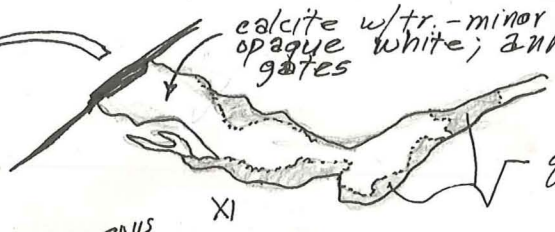
below 8095.8 ⇒ an EP-FEAX veinlets up to 9 mm. wide, with prominent bleached selvage

this one 1/s the stage 2 veinlets, another, nearby dips in the opposite direction at 30° (this one avg ∩ 1.5 mm. wide.

RECONN.
NOTES
10/07/90 A.M.
J. Hulen

HV 94-25
8242.6' - ~~8244.5'~~ - 8243.6'





NOTE: Many of the veins in the deeper reservoir have this same ~~cotted~~ contorted aspect, but lack calcite (see, e.g., Vega-17; instead, the calcite is replaced by FeOx & epidote aggregates or the calcite is dissolved and the resulting vugs ~~filled~~ lined w/ those minerals.

The textural similarity (contorted aspect) of the veins themselves is very compelling strongly supports dissolution/replacement of the pre-existing calcite as a major mechanism for ϕ creation.

(i.e. closer to "felsite")

probably contains sparsely disps. v. fxln syngenetic (?) sulfide (py

"a": sparsely sandy to silty argillite, v. dk. gray, prominently foliated/bedded w/ subtle soft-sediment-deformation features preserved — rock includes sandier slightly contorted lenses, which possibly could be termed argillaceous silty f.g. lithic MGRW

"b"

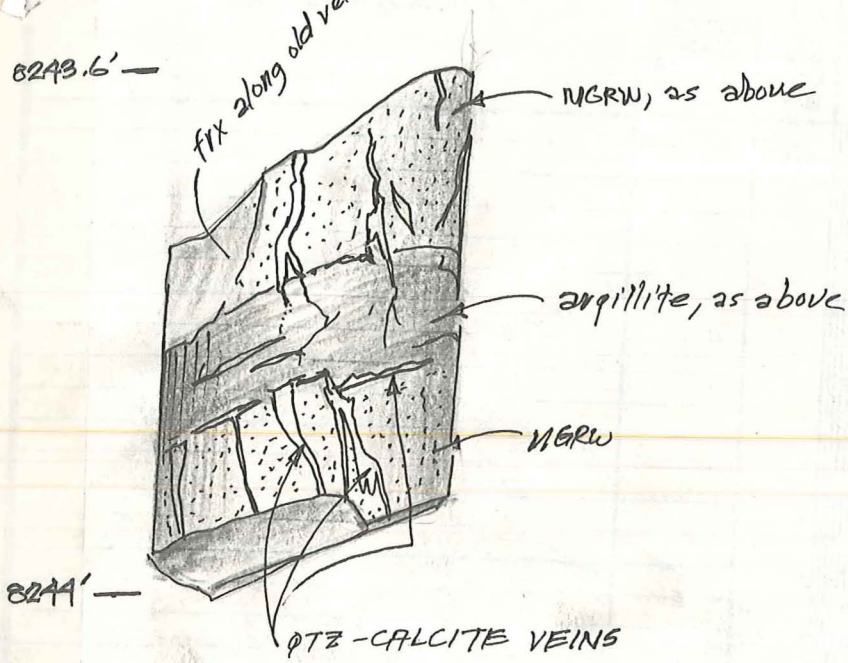
"c" Med-gr lithic MGRW, lt.-med. gray to greenish-gray, w/ abundant dk gray shale/argillite chips slightly larger than avg. grain size.

"a" is sparsely cut by randomly-oriented qtz-cal & cal veinlets avg <0.5 mm. wide (1% or less of total rock volume) a few // foliation (EXCEPTION: contorted vein just below 8242.6')

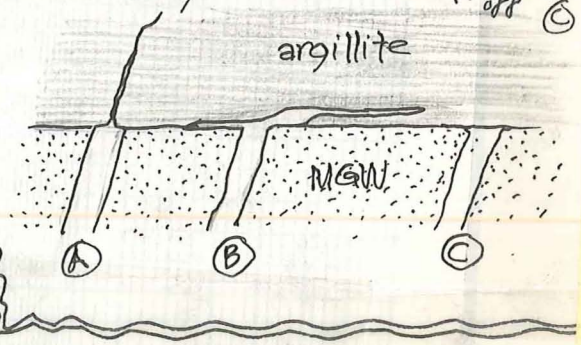
"c" is heavily veined — predominantly sub-⊥ to bedding/foliation — apparent width avg 1-1.5 mm., up to 10 mm — QUARTZ & QUARTZ-CALCITE

HV-94-25

NOTES: 10/07/90
J. HULEN



Note: v. strong rock-type control on veining
7-10% (vol.) vns in MGRW,
1-2% in argillite;
some veins in GRW narrow down dramatically when they enter the (A)→ARG.; some change attitude entirely — following bedding in the argillite (B); some appear w/ off (C)



RECONNAISSANCE NOTES

Sample Identification	Petrographer/Date of Examination
GDCF 15D-28 A	J. Auler 09/25/90

Rock Type
f-m gr. lithic Metagraywacke

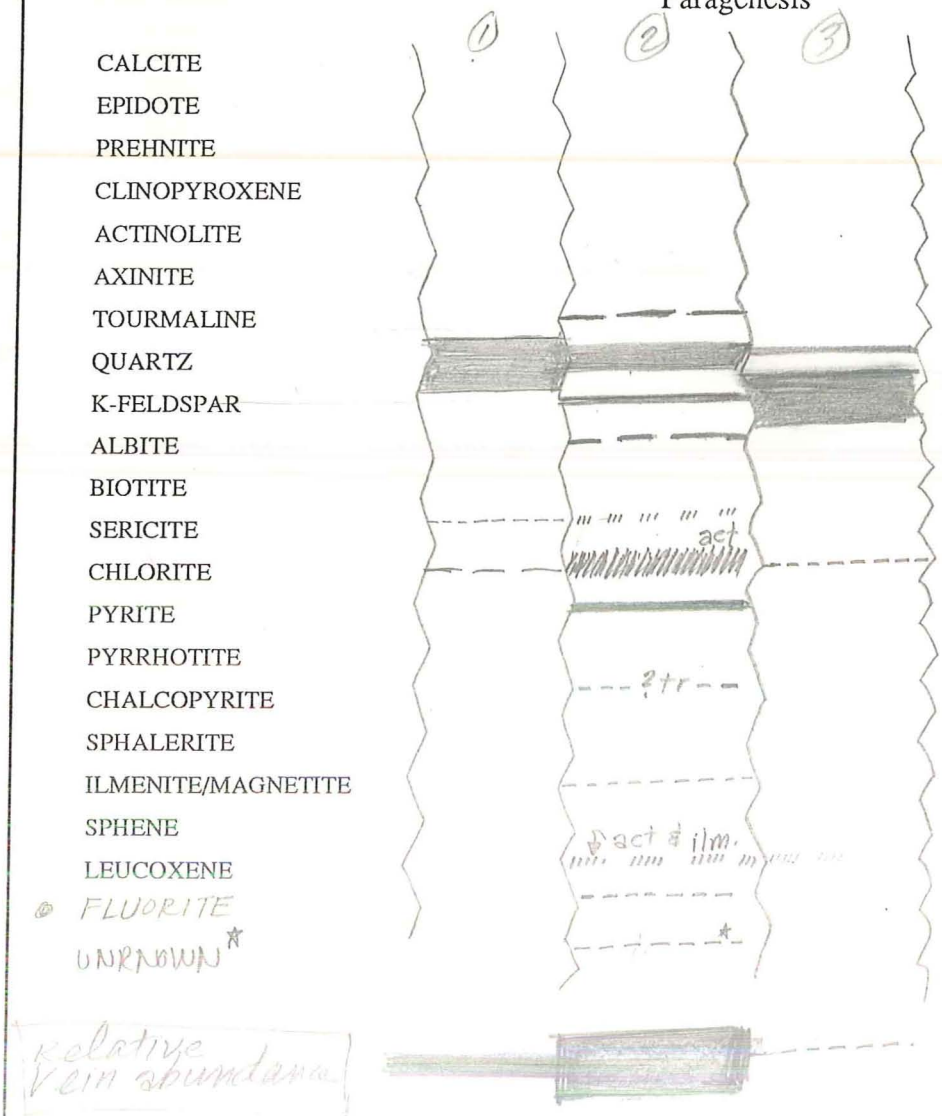
Fracturing/Brecciation/Veining and Vug-Filling
intensely veined
vnlts account for ~10% of TRV, random orientation
clear K-feldspar late mineral in stage ② vnlts. — they infilled w/ pyrite

Alteration/Metamorphism
diss. tourm.
chl./act in vnlts
greenschist (?) metamorphism
one clot FeOx & tourm. intergrown — looks like FeOx replaces tourmaline but can't say for sure.
no visible biotite

Fluid Inclusions
② abund., <1–10u, dom. v-rich, some liq.-rich w/ L:V ≈ 3.5/1 to 4/1 (2nd ?)
some 3/1
planes of v-rich incl.

Porosity Summary est. TP ϕ < 0.3% — some open

Paragenesis



1 = after

* v. high relief, tabular to blocky, anhedral, // extinction, 2 cleavages ortho gonal
partially replaced w/ sericite flakes.
↳ (or maybe just including)

GRAPHIC LOGS

DEPTH

ALTERATION — SEE DESCRIPTIONS — WMS | WMS | WMS | WMS | WMS

FRACTURING — WMS

VEINING & VUG-FILLING — WMS

VEINLET & VUG-FILLING PHASES — QTZ | EP | TOUR | CHL | EP | KF

GRAPHIC GEOLOGY

NOTES, COMMENTS

5017

FRAC DIP 80°

FRX ∠5°

ARG

5018

FRX 70-85°

19

RUBBLE

20

DESCRIPTIONS

poss. incipient hornfels — brownish

5017 – 5020 Argillaceous, f-gr. lithic MGRW, dk. greenish gray to med. greenish-gray, "bleached" to lt. greenish-gray locally.

ALTN.: ≈ 25% of the rock is "bleached" in vein selvages ranging from ∠0.5–3 mm. in width & in one broad 13 mm. band w/o obvious central vein; this dips ≈ 30°, has gauzy borders. There are also numerous qtz-ep. ±?) vnlts in a prominent set dipping 70–75° in the same general direction; Looks like there are early tourm-rich vnlts, later-stage ep-qtz-ch-rich veinlets; overall, veinlets plus selvages account for 20% or so of the total rock volume. ↳ vnlts 7–10%

This core consists principally of rubble below about 5018.2'; pcs. range from ∠5 mm to 10 cm. maximum dimension. fracture surfaces bounding the rubble chunks have basically random orientations. some have broken along veinlets; others have no obvious contrd.

The apparent vein paragenesis is as follows

① tourmaline-qtz-chl (± ?) ∠0.5–3 mm (avg ≈ 0.7 mm.) wide — irregular, most dipping at fairly high (>50°) angles — "soaked"-into-matrix appearance ∠1% of total rock volume

② qtz-EP (??)-CHL ± (the bleached areas described above.

③ qtz-KFSP-(-EP??) 1–2% of TRV, ∠0.5–3 mm wide, commonly vuggy — vugs up to 7 mm × 2.5 mm. in X-section

④ (POSSIBLY!) late K-sp + qtz ∠0.5% of TRV — coat some late-stage frx.

DRILL HOLE GDCF 15D-28

LOCATION

LOGGED BY HULEN

10/04/90

RECONNAISSANCE NOTES

Calculation Record

UNOCAL 76

PREPARED BY	CHECKED BY	DATE	PAGE
HULEN		10/04/90	OF

SUBJECT: GDCF-15D-28

W.O./A.F.E. NO:

IMPRESSIONS

The rock looks mostly like a hornfelsic metagraywacke — med.-dk brownish, which has been bleached (altered) hydrothermally along well-defined ν fractures as well as in larger amorphous patches & gauzy broad bands — the "bleaching" could involve creation of epidote, illite, feldspars (can't say for sure) but it has a lt. greenish to slightly yellowish-greenish aspect. — There are a few widely scattered vugs in late-stage qtz-kfsp-rich veinlets, but they are fairly widely sparsely dissem.

- no obvious hydrothermal breccias or hydraulic-fracture stockworks
- looks overall like poor ϕ, although the rubblized aspect below 5018.2' could indicate fracture ϕ

XRD → • a few of the fragment-bounding fracture surfaces appear to have coatings of v. late-stage euhedral stubby monoclinic crystals — some of these have a cubic or pseudocubic aspect

RECONNAISSANCE NOTES

Sample Identification	Petrographer/Date of Examination
GDC-30-Fh	J. Hulen 09/23/98

Rock Type vf-med. gr. LITHIC METAGRAYWACKE

Fracturing/Brecciation/Veining and Vug-Filling
crudely orth. vnlts 4-5% of TL rock vol.
vnlts ≤0.1-2 mm. wide - no real evidence of shearing

Alteration/Metamorphism
Greenschist met. - conversion of matrix to ill./chl. aggregates, then poss. recrzn. of these, in part, to light brown phengite — INCREDIBLY BEAUTIFUL BERLIN BLUE CHL (XNIC)

Fluid Inclusions
① abund; ≤1-12μ, 98% vap-rich, irreg.
② many liq-rich pr. & 2nd, L:V in 3/1 also abund. vap-rich (planes common) est. >260°C

Porosity Summary ~3%(?) mostly intercrystalline vugs in stage ② vnlts and in late-stage ν fractures; good ν in layer silicate aggregates, in fine-X/n. qtz of stage 1 vnlts, & in albite of stage ② vnlts.

Paragenesis

est. TL% vn. minerals/veining 4-5%

	①	②
CALCITE		2
EPIDOTE		
PREHNITE		
CLINOPYROXENE		
ACTINOLITE		1 - ? - ? ★
AXINITE (FERRO)		1
TOURMALINE		1
QUARTZ		1
K-FELDSPAR		⊛
ALBITE		2
BIOTITE		
SERICITE		≠
CHLORITE		2
PYRITE		
PYRRHOTITE		
CHALCOPYRITE		
SPHALERITE		
ILMENITE/MAGNETITE		1
SPHENE		2
LEUCOXENE		3
WAIRAKITE		3

open, mostly following chl.-rich stage 2 vnlts.

vug-filling, poss. post-dating other vein minerals

VEIN replacive abundance

★ needles encapsulated in quartz.
≠ acicular bundles - probably after actinolite
⊛ appears to replace K-feldspar (??)

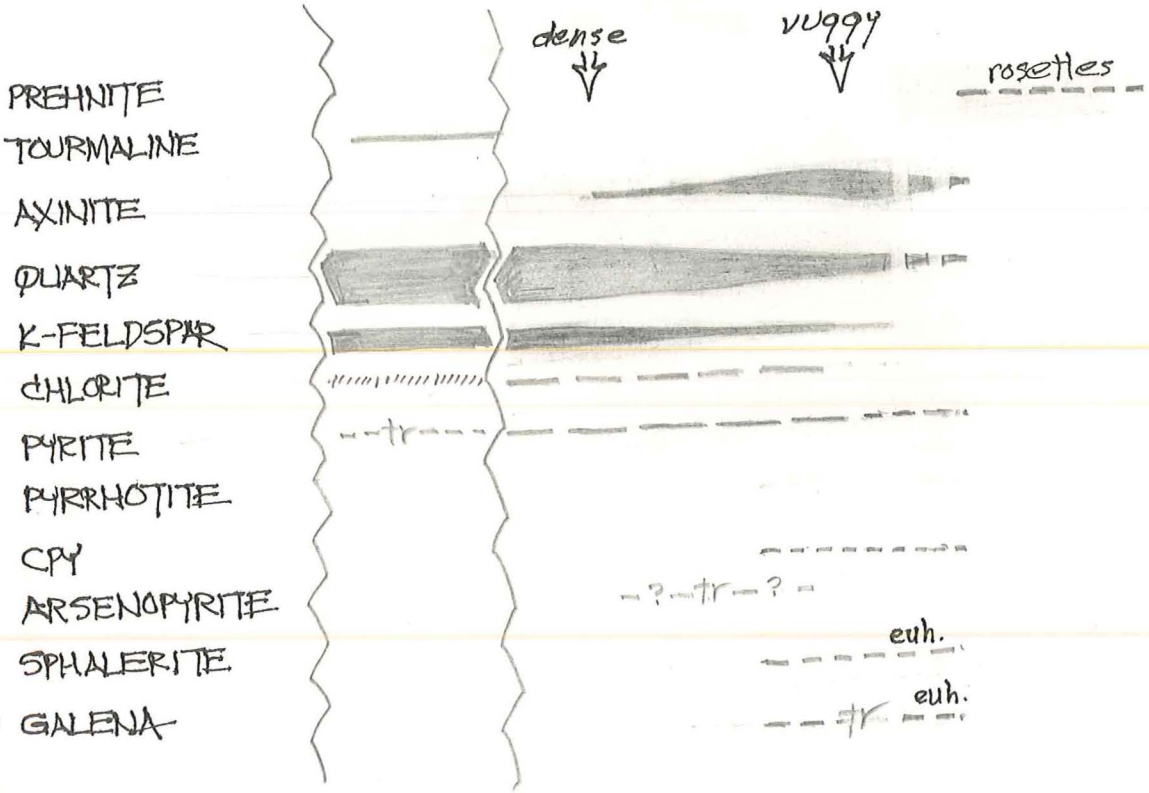
≤1
>1-5
5-15
15-50
>50
%

REPLACEMENT

GDC-30

J. Hulen
10/05/98
RECONNAISSANCE NOTES

VEIN-MINERAL PARAGENESIS
5021-5022'



RECONNAISSANCE NOTES

GRAPHIC LOGS

DEPTH	ALTERATION: WMS	WMS	WMS	WMS	DISS. TOUR. WMS	FRACTURING: WMS	VEINING & VUG-FILLING: WMS	VEINLET & VUG-FILLING PHASES: QTZ	KFSP	PREHNITE	AXINITE	TOURM.	CPY	CHLOR.	SPHAL.	GN	PYRITE	GRAPHIC GEOLOGY	NOTES, COMMENTS	DESCRIPTIONS
5012'																				5012-5013': Rubble: hornfelsic(?) MGW and
																			RUBBLE	argillite, similar in overall texture to
																			GEN. "BEDDING"/ SHEARING @ 45° DIP	GDCF 150-28 core; dense, flinty, med.
5013'																			SAWN	brn, but extensively "bleached" to lt.
																			avg. GW	yellowish-greenish-gray along
																				extensive microveinlets and bands
(D)																			GW	sub// to bedding — suspect these
																			VNLT. DIPS 85°, 50°, 65°	are silica, 2 fsp., & epidote ✓T.S.
5014'																			NO VUGS	NO OBVIOUS VUGS.
																			(Rubble)	5013: Argillite & arg. MGW, as above;
NOTE: SULFIDES SPARSE TO ABSENT																				abund. veinlets but many v. "remobilized"
																				appearing — no vugs. one stage of vein-
																				let (unclear which) shows diss. dark
																				equant opaque (ilmenite?) ← could be
																			cont. dip @ 35°	TOURMALINE VEINLETS.
5015'																			rubble-appr. random fracture orientation	@ 5013.5 — gives way to stockwork veined
(G)(?)																				MGW >2 vns/cm paragenesis unclear
(1★)																				mostly QTZ & CHL, prob. local tourmaline
																			(★)1	tr. epidote? vns. ave < 0.1–2 (avg. ~
5016																				0.7) mm. wide, w/ bleached, creamy sel-
																			GW	vages extending up to 2 vn. widths out.
(2★)																			intense vng. attn.	veinlets rarely coalesce to form irreg.
(E)																				clots up to at least 2.5 mm. maximum
5017'																			conspic. bleaching	dimension.
																				A.A Frx follow old vnlts in large part.
																			bx dip @ 55°	band of jigsaw-puzzle breccias and vnlt stockwork dip @ 55° — cemented by
(F)																				QTZ-CHL-TOURM ± KFSP, poss albite
★ but strong "bleaching"																				"bedding/shearing dip @ 50°: intbd. arg. & gw w/ frx & bxtn. selectively developed in GRW (but not in the coarsest-grain variety.
5018'																			many vnlts // bedding	ARG. & GW/W/ strong rock-type control on
																				fracture/vein intensity: GW is intensely
																				stkwk vnd.; vnlts have selvages, bleached
																			ARGW/GW CONT. DIP 70°	≤1.5 vein widths. — <0.1% VUGS.
(B)																				GW, mod. vng. (✓ for WAIRAKITE)
5019' (H)																			FRX 85°/75°	opp. dips diss. tourmaline picks up to 7-10%
																			MAJOR FRX COATED W/ WHITE	of rock. bleached-appearing vnlt. stkwk.
(★9)																				mostly GRW, minor arg. — GRW is v. complexly
																			MINRL. V75° OPPOSITE TO	stkwk-fractured/veined.
																				early tourmal-QTZ-KF-CHL — later
5020																			GW/ARG. CONTACT V75°	unknown white vnlts. ± CHL.
																				← HYBAUL FRX/VNLTS // argillite as above
																			RUBBLE	appearance of COMMON VUGS AT
																				~ 5020.5'
(C)																				Appearance of later-stage QFSPCHL-
5021																				PY (-tr FeAx) veinlets up to 9 mm. wide,
(★4)																				locally coalescing or "blooming" to form
A BIG CHANGE (★5)																			rubble	irregular masses up to 2X1.5 cm in
																				X-section; these are commonly vuggy
																				(see note (4)).
																				SPHALERITE, GALENA, CHALCOPYRITE, PREHNITE, APPEAR IN TRACE TO MINOR AMOUNTS
																			VUGS!	← rubble: see note (5)★

DRILL HOLE GDC-30

LOCATION

LOGGED BY J. HULEN

10/04/90

* RECONNAISSANCE NOTES

JBHutter 10/05/90

GDC-36

Impressions — Vein minrlz in the upper 9'± of this core is dominated by qtz-tour-kfsp chl. ± rare tr. of sulfide — the veins/veinlets/vnlts occur in complex stockworks, are locally aligned as moderately-dipping sets, locally have invaded along bedding. The veining is accompanied by locally pronounced "bleaching" of the normally brownish-gray host rock to lt. greenish-gray to creamy white — "bleaching" occurs as vein selvages ± as larger irreg. masses w/ obvious control, but probably where ultra-vnlts coalesce/are concentrated — locally abund. diss. tourmaline in these "bleached" areas, particularly in coarser grained metaclastics — probable hydrothermal breccia dikelets locally present — differential response to stress (MGRW-dominated areas in general much more intensely fractured than Arg.-dom. areas)

lower foot, vuggy QTZ-KF-FeOX veins appear. The vugs contain traces of euhedral sphalerite and galena with ank. chalcopyrite. Then v. latest-stage prehnite rosettes.

Calculation Record

UNOCAL 76

RECONNAISSANCE NOTES

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SUBJECT: GDC-30

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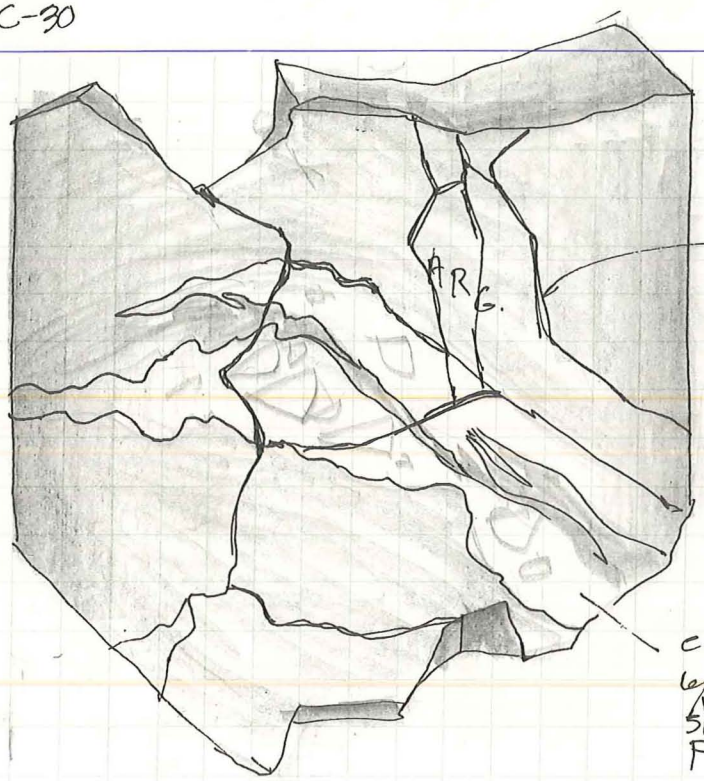

(★1)

late, open frx — stkwk, some follow veinlets/masses, some (most) with no obvious control.

QTZ-CHL (/act?)

complexly veined grw-bx w/ crenulate/lobate ~~boot~~ borders
sheared-appearing (re-mnrlz. Franciscan?)

(★2) incredibly complex stkwk fracturing, silicification, KFsp flooding, veining — chl-rich vn/lts apparently post-date everything but paragenesis is quite ambiguous.
sulfides conspicuously absent.

(E) Basic rock color is med-dk grayish-brown, but in this & other pcs. the rock has been "bleached" along a myriad of stockwork fractures mostly <0.5 mm. wide — where these coalesce, the entire rock is bleached; further → the "bleaching" seems to also invade bedding planes AND it seems to have accompanied emplacement of tourmaline-bearing veinlets.

(F) Paragenesis fairly clear:
① QTZ-CHL ± TOUR, KFSP
② QTZ-KF-CHL (locally a few vugs <1 mm, lined w/ euhedral)
③ OPAQUE WHITE (POSSIBLY ALBITE)(POSS. WAIRAKITE)

(B) @ 5018.9' — a few chunks for XRD, w/ the prominent opaque white mineral as above
(some pcs. easily peeled away from fracture surfaces)

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UNOCAL 76

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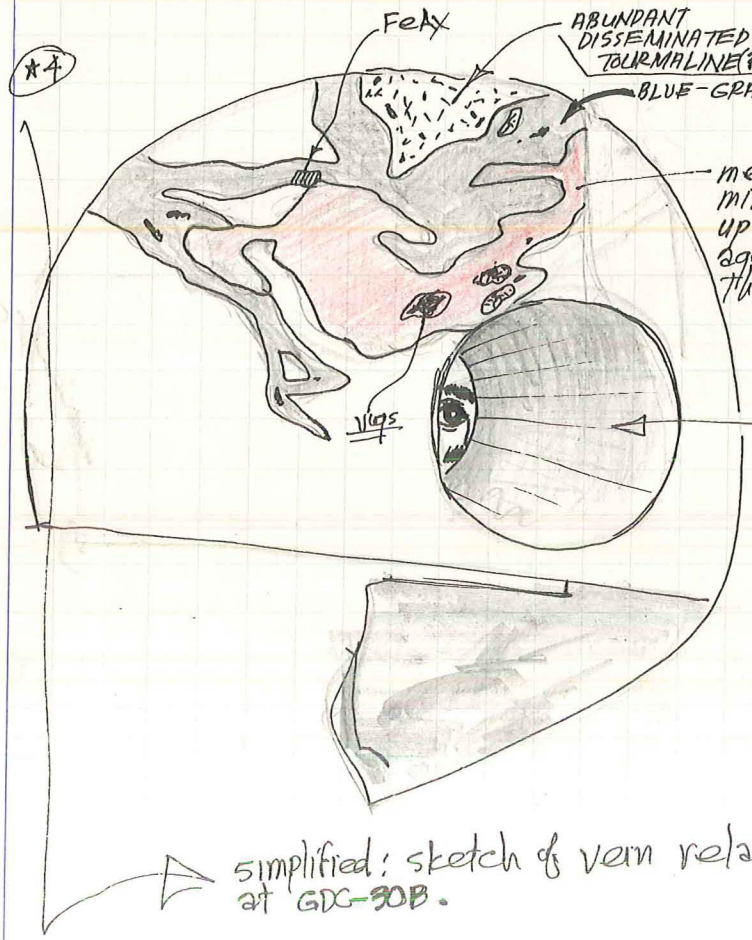
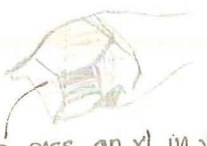
SUBJECT: GDC-30 | W.O./A.F.E. NO.:

(★3) There is a late-stage white mineral which has controlled some subsequent fracturing: by contrast with the earlier tourm-bearing veinlets, these late white ones are "frozen" to the walls; some can be easily picked off for analysis (not); the early tourmaline veinlets locally coalesce to form ± to irreg. larger aggregates, some of which are actually cemented "jigsaw-puzzle breccias"; possibility that there are some late chlorite microveinlets.

(★4)



simplified: sketch of vein relationships at GDC-30B.



sp, poss. gn xl in vug 2.5mm dia.

(★5) Rubble from 5021-5022:
intermixed lithic MGW & argillite, complexly fractured & vuggy veined. numerous large vuggy QTZ-FSP±FeAx± sulfide clots as above (see log right above 5021 & sketch to immediate upper left). — these vugs, though, are up to at least 15 mm. in diameter. —
FeAx has become much more common (lining around)
- In and around a few of these vugs, the FeAx & quartz are intergrown with euhedral SPHALERITE & GALENA
  - sp. xls. up to 2.5 mm. diameter
  - gn " (much rarer) up to 1.5 mm. dia.)
  - also euh. pyrite ≤1.3 mm
  - cpy forms irregular clots seemingly deposited earlier than the other sulfides.

Latest vug mineral deposited is PREHNITE, as rosettes of pearlescent greenish-gray (light-) scales perched on the other vug-filling phases

RECONNAISSANCE NOTES

Sample Identification	Petrographer/Date of Examination
SB-31-H-h	J.B. Hulen 09/26/90

Rock Type compound hydrothermal vein cutting brecciated & extensively silicified, f-m-gr lithic metagraywacke.

Fracturing/Brecciation/Veining and Vug-Filling Rock has been complexly fractured & brecciated, w/ most frx & intra-breccia voids filled w/ the vein minerals reported below.

many planes of vap-rich incl.

Alteration/Metamorphism

some vug layer in silicates.

GOOD EVIDENCE FOR BOILING

② abund., dom. vap-rich, dom. 10's, <1-10 μ, some fine liq.-rich primaries in qtz. & kfsp. w/ L:V ≈ — these. v. irreg., esp. in K-feldspar

Fluid Inclusions

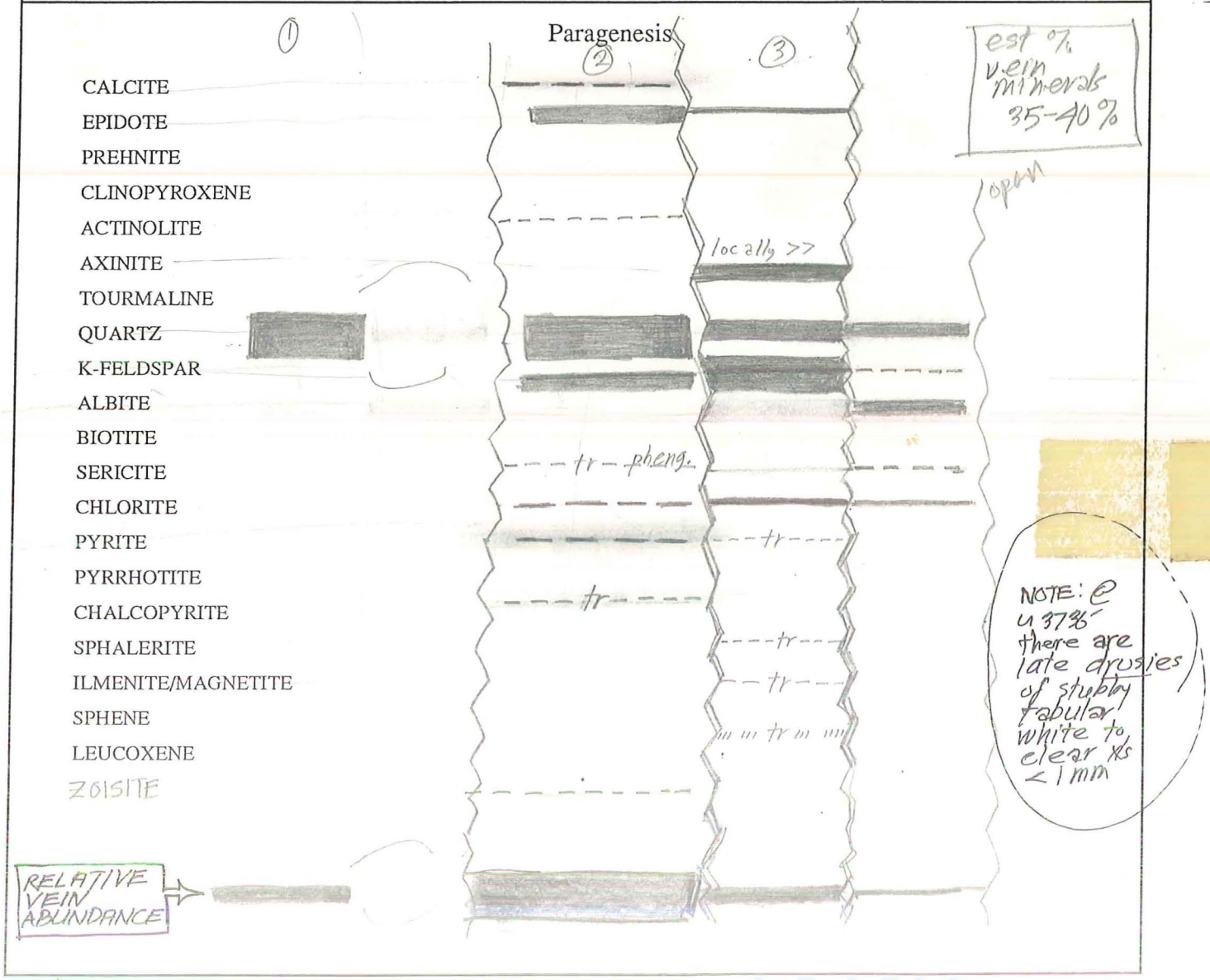
① vi. abund., avg. << ½ μ, mstly vapor-rich

③ x – v. abund.; dom. vapor-rich avg. ≈ 2-4 μ, some liq-rich w/ L:V ≈ 3.5-4/1 (QTZ)

④ ?

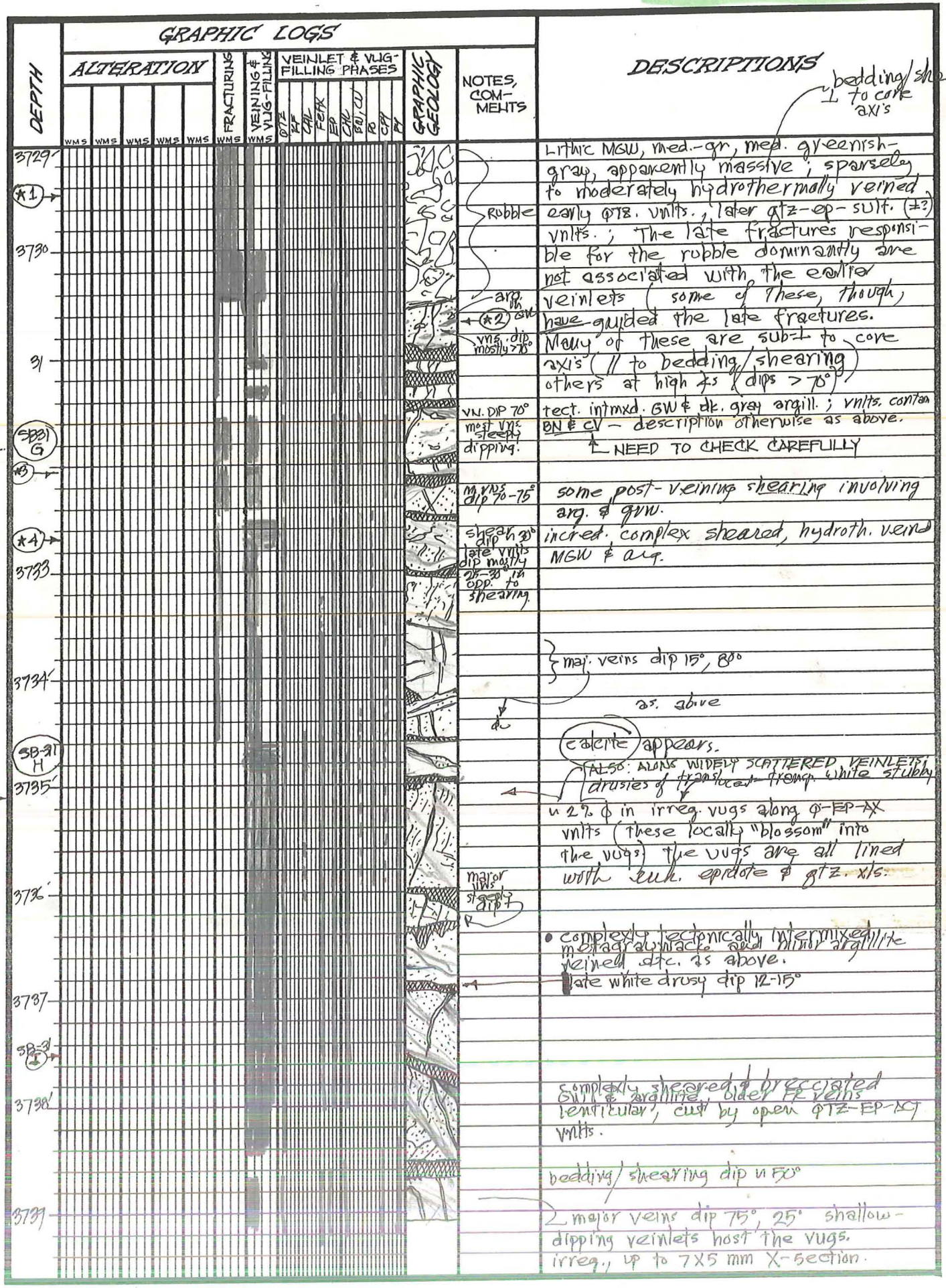
Porosity Summary est. TL φ ≈ 2% — bulk as intercrystalline vugs in stage 2&3 veinlets: those in qtz. & ep & ax. appear to be primary — those in Kfsp. poss. dissolution

Paragenesis



tr
<1
1-5
5-15
15-50
>50
ABUNDANCE, %

RECONNAISSANCE NOTES



DRILL HOLE SB-31

LOCATION 3729 — 3750

LOGGED BY J. HULEN

10/03/96

RECONNAISSANCE NOTES

DEPTH	GRAPHIC LOGS: ALTERATION (WMS WMS WMS WMS WMS)	FRACTURING (WMS)	VEINING & VUG-FILLING (WMS)	VEINLET & VUG-FILLING PHASES (QTZ KF CAL FeOx EP CHL BN,CY Py CPY PO)	GRAPHIC GEOLOGY	NOTES, COMMENTS	DESCRIPTIONS
3739'					?		
SB-31 J							
3740'							GRW/ argillite as above
3741						"bedding dip ± 60°	argillaceous GW; veining diminishes.
(K)						PRINCIPAL	VEINLET DIP ± 80°
3742						RUBBLE	GW & argillite as above
3743 (L)						shearing dip abt. 65°	interleaved GW & argillite, as above w/ increase in veining also a ½" wide, hydroth. bx vein // to bedding/shearing. vnlts & bx dikes mostly // to but also ⊥ to bedding shearing
3744							As above: interleaved MGW & argillite, w/ hyd. bxn & Φ-Pyr-Ep-(KF?) veining concentrated in the GRW.
						(A8)	— SEE SKETCH —
3745							As above: would characterize the entire rock mass as being stockwork fractured w/ local hydrothermal brecciation, but response to stress & resulting vein intensity strongly controlled by rock type; GRW beds/lenses have brittly fractured, commonly ⊥ to bedding; arg. beds/lenses have far fewer veins — responded to stress by SHEARING. There is also evidence of post-vein shearing — vnlts in MGW cleanly truncated by argillite in some cases; EST overall 10-15% VN/VUG in MGW, 2% in ARG. ΦTZ-EP-SULF±FeAx veinlets range from <0.1 mm to 5 mm. in thickness, locally coalesce to form angular to irregular clots up to at least 40 mm. maximum dimension.
reversed. 3746 (N)						HYDROTH. BRECCIA	
HYD. BX common (9*)						FRAC. DIP 25° COATED w/ euh. transp. white stubby euh-sh. Xls.	
47						HYDROTH. BRECCIA	
(M)						24° DIP FRAC. w/ white transp. Xls as above	
48						Frac 85°	NOTE: THE veins, esp. the larger ones, contain a few XL-lined, lenticular to irres. VUGS up to at least 12 mm. max dimension
49						to 3750' Rubble	
3750						stk vnd. as above	

NOTE: THE PYRRHOTITE IS WIDELY OXIDIZED AT THE CORE SURFACE

THE CLOTS COMMONLY CONTAIN 2 WILL ROCK CLASTS IN "JIGSAW PUZZLE" TEXTURES

DRILL HOLE SB-31

LOCATION

LOGGED BY J. HULEN 10/03-10/04/90

RECONNAISSANCE NOTES

Calculation Record

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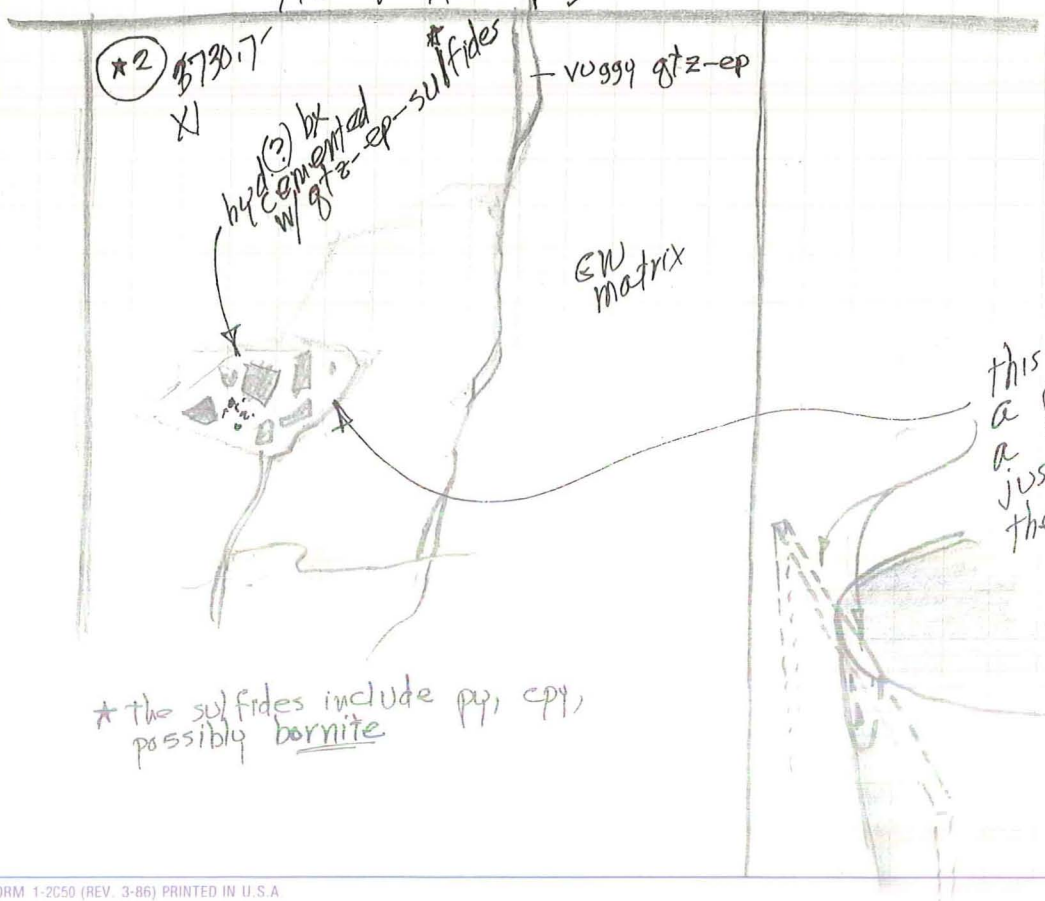
SUBJECT: SB-31 | W.O./A.F.E. NO.:

★1 @ 3729.5' : vuggy qtz-ep. vn. <0.5–5 m. wide, vugs <0.5–4 mm in X-section vugs lined w/ euhedral xls.

● NOTE: 3730–30.5 - irreg. Franciscan qtz. vns/aggregates in rubble chunks — these up to at least 2 X 1 X 1 cm. in size, have been fractured & veined themselves w/ qtz-ep.

think about this as a dissolution cavity in the Franciscan vein (used to be calcite?) has the look

med.–xln Franciscan quartz, complexly veined w/ later qtz–& qtz-ep. vnlts



★ the sulfides include py, cpy, possibly bornite

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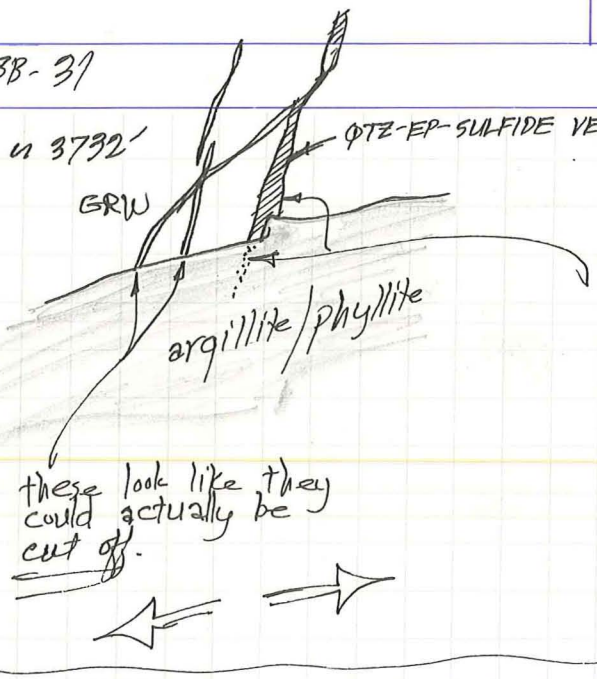
(3★) @ 3732'

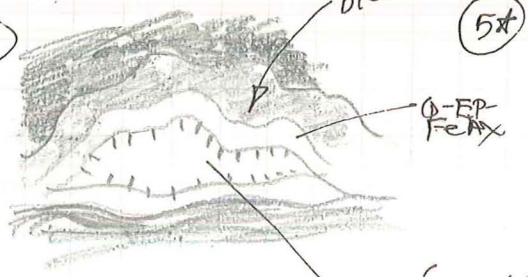
XI



vnlt. not really cut off — just looks like the GRW is more dilatant — the argillite seems to have reacted to stress by shearing, rather than fracturing.

(4★) incredibly complicated shear/vein zone
early (stage ① & ②) vnlts are caught up in part as clasts in subsequent shearing
later ③ veinlets X cut the sheared earlier vnlts.
both ② & ③ are partially vuggy — vugs lined w/ qtz, KF euhedra — < 3 mm. maximum dimension.

(5★)



(5★) A number of vugs have formed in QTZ-PO-FeAx EP veinlets within & along a shear zone in argillite

impression — these look like dilatant zones in a shear, not really hydroth. breccias.

Q-EP-FeAx

Calculation Record

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SUBJECT SB-31

W.O./A.F.E. NO

(★5)

In this pc, GRW is intensely stockwork fractured, veined, while the intervening argillite/phyllite septa are only sparsely veined; the epidote-bearing veins locally merge into irregular vugs ranging in size from 1 mm or less to 15X10 mm in X-section; the vugs are lined w/ euhedral x/s., but their margins are very irregular. (dissolution?)

veins easily 5-7% of (TRV)

Calculation Record

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RECONNAISSANCE NOTES

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SUBJECT 5B-31

W.O./A.F.E. NO.

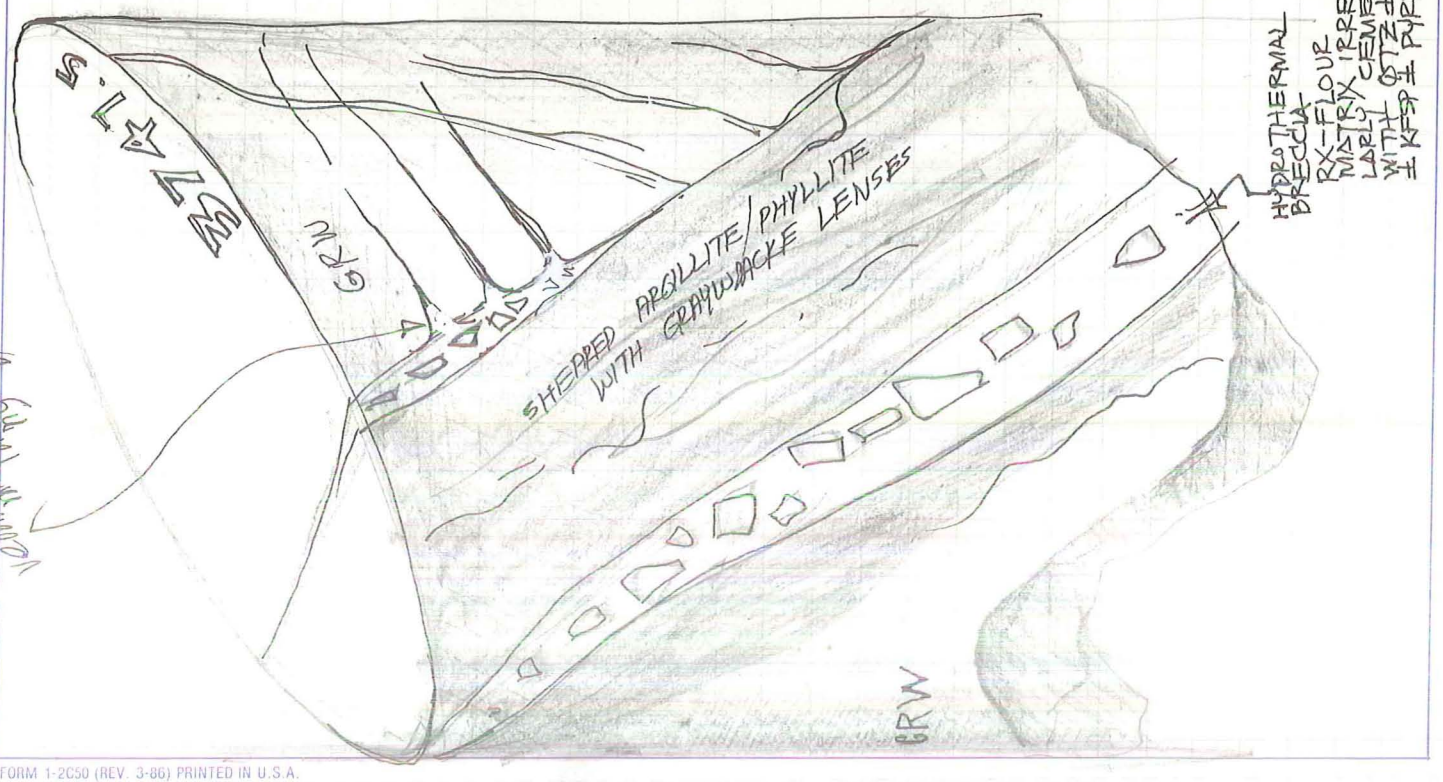
PRELIMINARY IMPRESSIONS

3729— Lithic METAGRAYWACKE, f.–med. gr., locally interbedded/tectonically interleaved/sheared w/ minor sandy argillite to phyllite; GRW lt–med. greenish-gray; argillite is med–dark greenish-gray;

complexly veined; sometimes barely discernible early Franciscan veining, then QTZ-EP± FERROAXINITE ± PYRRHOTITE., then later quartz-~~chl~~ chlorite; the veining could really be considered a stockwork mostly randomly oriented, with some // to "bedding", some (many) at high ∠'s to bedding, some following contacts between arg. & MGW. Clearly a rock-type control — GW much more heavily veined than arg. — there has been some post-vein shearing, cutting off GRW-hosted veins at argillite contacts

Many of the stage ② veins are vuggy — w/most vugs irregular.

NOTE #7



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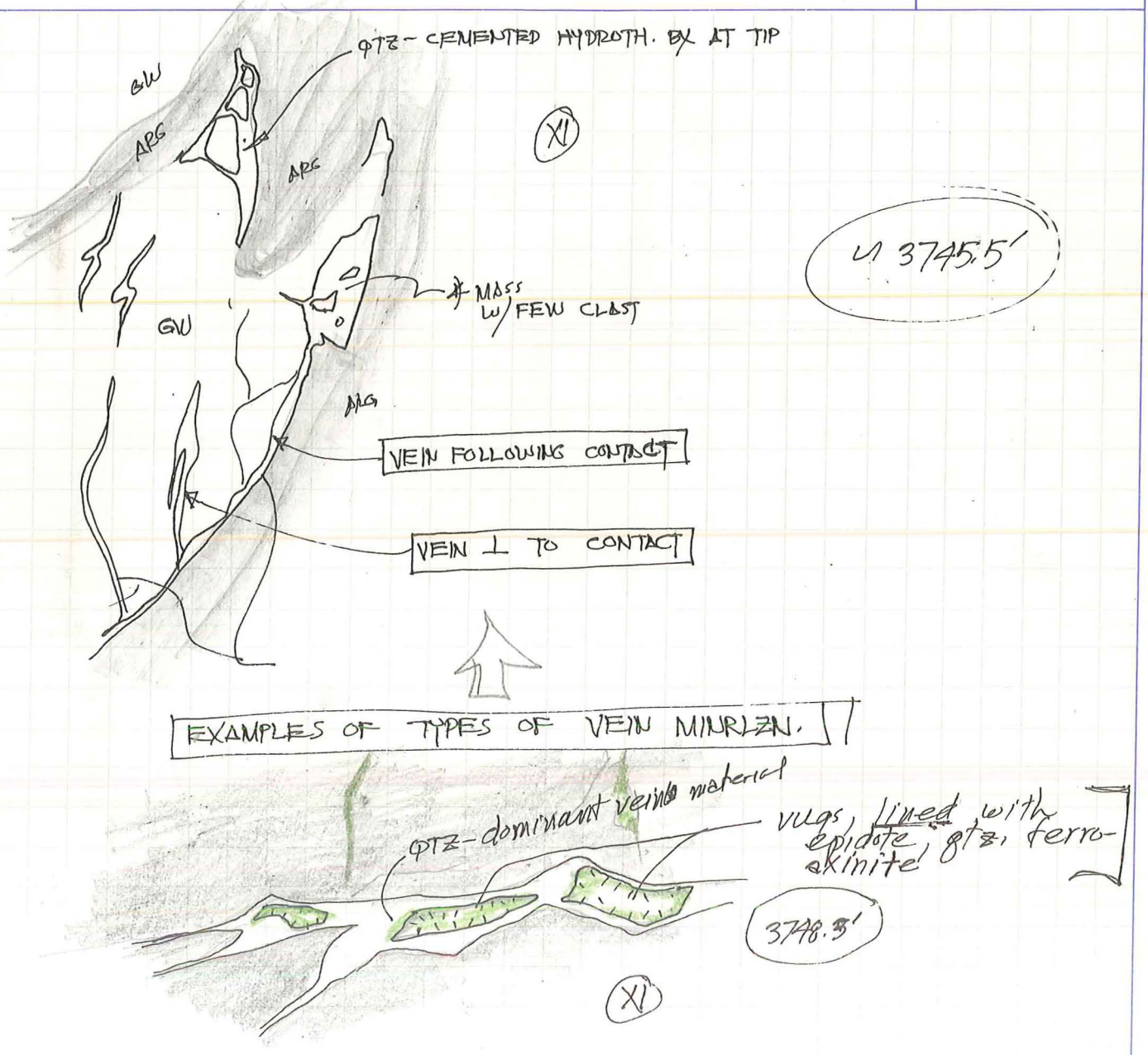

NOTE THAT ALL THE VUGS ARE ASSOCIATED W/ STRONG EPIDOTE ENRICHMENT

(this provides support for the calcite-dissolution & development hypothesis.

Calculation Record

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SUBJECT: SB-31

W.O./A.F.E. NO:

(*8)

(*9) u 3745.8 - 3747.4': INTENSE HYDROTHERMAL BRECCIATION OF MGRW PORTION OF THIS CORE, W/ STEEPLY-DIPPING (>75°) VEINS OF JIGSAW PUZZLE BRECCIA, UP TO AT LEAST 10 MM. WIDE CEMENTED BY ΦTZ-EP-PY±PO (↑ FOR FERROAXINITE) W/ LOCAL, IRREGULAR YUGS UP TO 12 (L) × 7 (W) MM.

RECONNAISSANCE NOTES

GRAPHIC LOGS

DEPTH | ALTER (WMS, WMS, WMS, VUG WMS) | FRACTURING WMS | VEINING & VUG-FILLING WMS | VEINLET & VUG-FILLING PHASES (QTZ-KFSP, EPID, CHL, FERROAN, PY) | GRAPHIC GEOLOGY | NOTES, COMMENTS | DESCRIPTIONS

✓ for FeAx higher than 8528'.

DEPTH	NOTES, COMMENTS	DESCRIPTIONS
8526	bedding dip ∩ 70°	8526– : Lithic Metagraywacke, med.-gr., lt.-med. greenish-gray; heavily vnd.– q-ep ± kf & ?, veins are vuggy; vugs up to 3 cm. max. dimension, v. irregular; est ∩ 4% vug ϕ
	vn. dip 55°	
	vuggy vein vertical	– refractured, slickensided vein surface 45° dip; don't believe this is polishing during the drilling process; early qtz. vn. dip 52° (maybe it is)
27		MISSING SAMPLE (PRESERVED FOR LATER ANALYSIS
		veining diminishes, vugs vanish, rock takes on a dark gray color.
28	beds dip ∩ 70°	pebbly, arg. med-crs. gr. Lithic MGW vein intensity picks up again • vug ϕ 3% or so • bulk of vnlts. dip > 70°
	vnlts dip at hi-45	
29		appearance of argillite and v. argillaceous f.g. MGW
	bulk of vnlts. dip >75°-90°	• just grazed older qtz. vn. at least 12 cm. wide, milky appearance, probable older Franc.-vintage
"jigsaw-puzzle" breccias common in here		
30		Rubble – mostly argillite
		interbdd. argillite and arg. f.g. lith MGW, MGW much more veined, comm. ⊥ to bedding. some shearing in argillite
31	PLUG	as above, w/ classic load structures & "ball-and-pillow" structures (turbidite) general beddings dip ∩ 70°.
32	2-6 mm vein follows contact. dip not ∩ cont. ∩ 50° dip	as above; vnlts. pick up a bit in the argillite (3% total vein volume), & many of the argillite-hosted veins show jigsaw puzzle textures. – VUGGY VEIN
	Rubble	
33	vns. dip 70° & 25°	8-10% veins + vugs, vns. up to 4 mm. wide. FG lithic MGRW, lt-med. greenish-gray – stkwk QTZ-KF-EP VNLTS. (beautiful)
34	RUBBLE	
	MAJOR VEIN DIPS 85°	As above, except veining & vug ϕ diminish.
35	do. 80° frx coated w/ qtz &	prob 7-8% (or more) vug ϕ appears to have undergone also a little post vein tectonic crushing (pass. a drilling artifact) a few late-stage drusies of <0.2 mm. Transp. whitish Xls ← ★
		arg. & grw as above
36		

late frx

vnr

vns mostly dip 75°

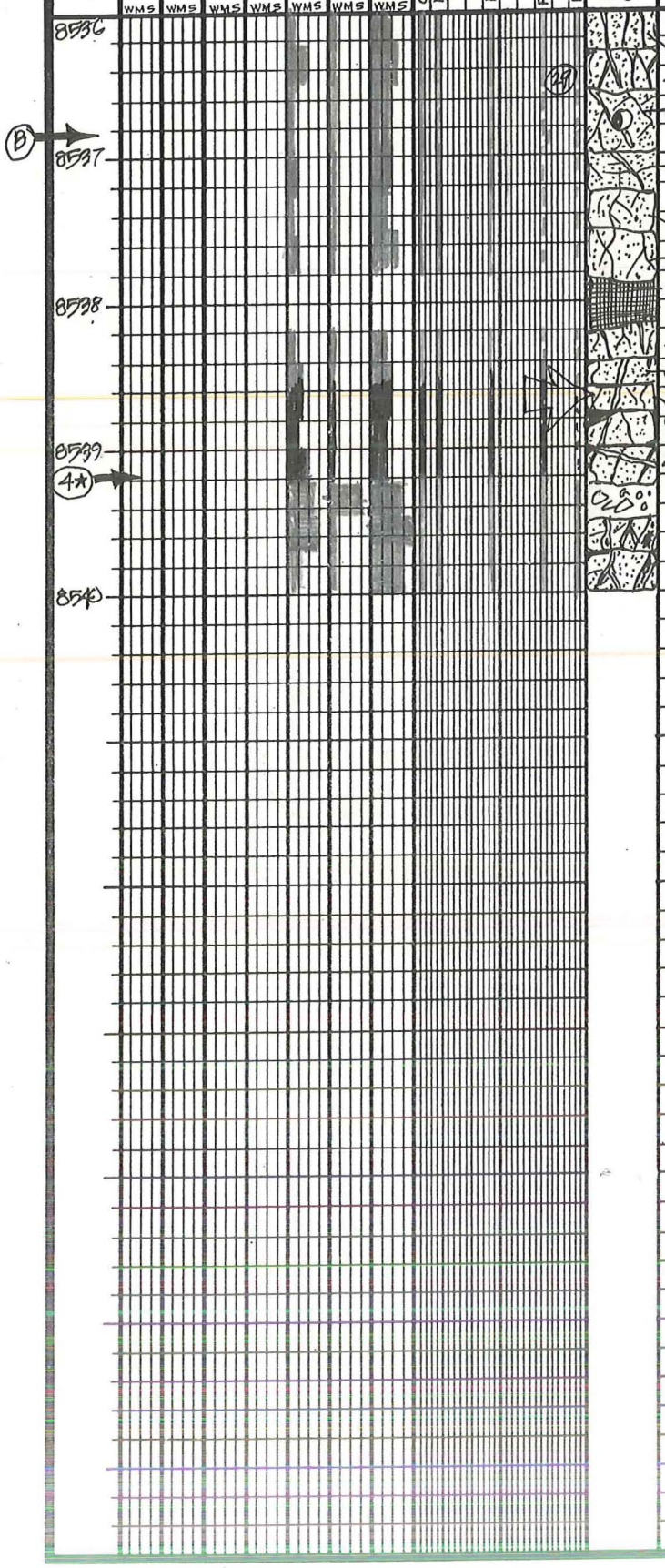
DRILL HOLE NEGU-17

LOCATION

LOGGED BY J. B. HULEN

10/06/90

RECONNAISSANCE NOTES



DRILL HOLE NEGU-17

LOCATION

LOGGED BY J. B. HULEN

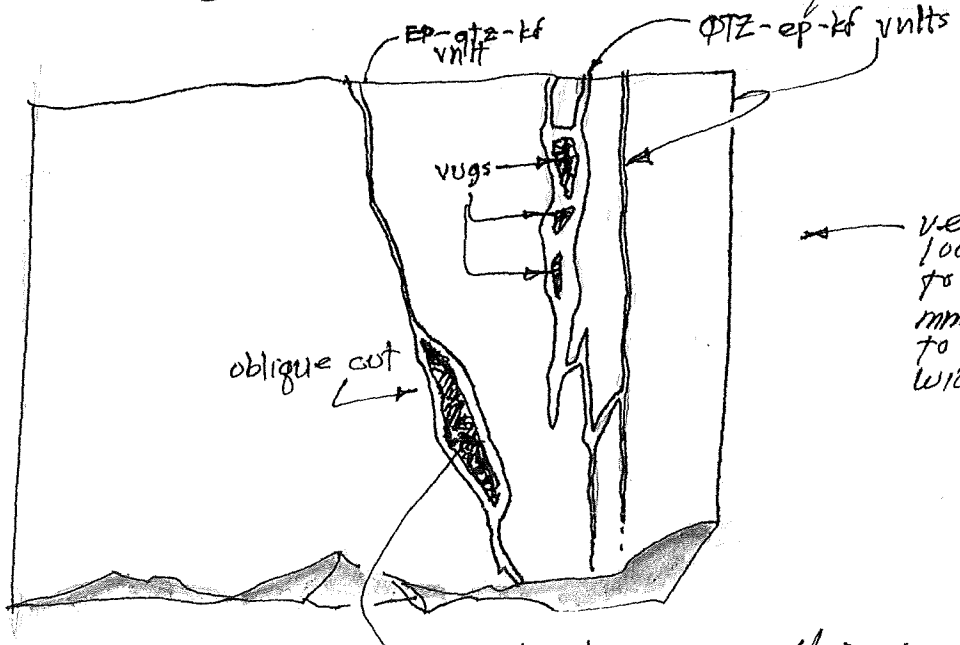
10/06/90

NEGU-17 RECONNAISSANCE NOTES J. HULEN 10/06/90

BB26-28'

Lithic Metagraywacke, med.-gr., lt.-med. greenish-gray; abund. (3-4%) argillite chips up to 6 mm X 2 mm in size (avg. 2X0.5); rock is stockwork veined w/ preferred orientation of vns >60°; the veins are <0.5 - 3 mm. wide (avg n 1.5 mm wide) locally coalesce into irregular to angular vugs up to 3 cm. max. dimension.; the vugs are invariably associated w/ enrichments of epidote, and are lined with euhedral epidote, qtz & K-feldspar x/s. up to 2 mm. maximum dimension; many of the vugs in the rock lack obvious connections with feeder veinlets — look more like "vesicles"; many of these have crudely rounded or lobate forms/outlines.

BB28.6



← veinlets here locally expand to at least 5 mm. wide — tend to be vuggy where wide

this is not dissolution of calcite in Franciscan-vintage vein — could be dissolution of calcite in later hydrothermal vein, or could be primary intercrystalline space.

relative to the vein itself

(★3) classic load structures, ss in mudstone (now lithic MGW in argillite); the ss. (MGW) is selectively fractured/veined at least 5X the vein volume as in the argillite

see drawing next page

NEGU-17

RECONNAISSANCE NOTES

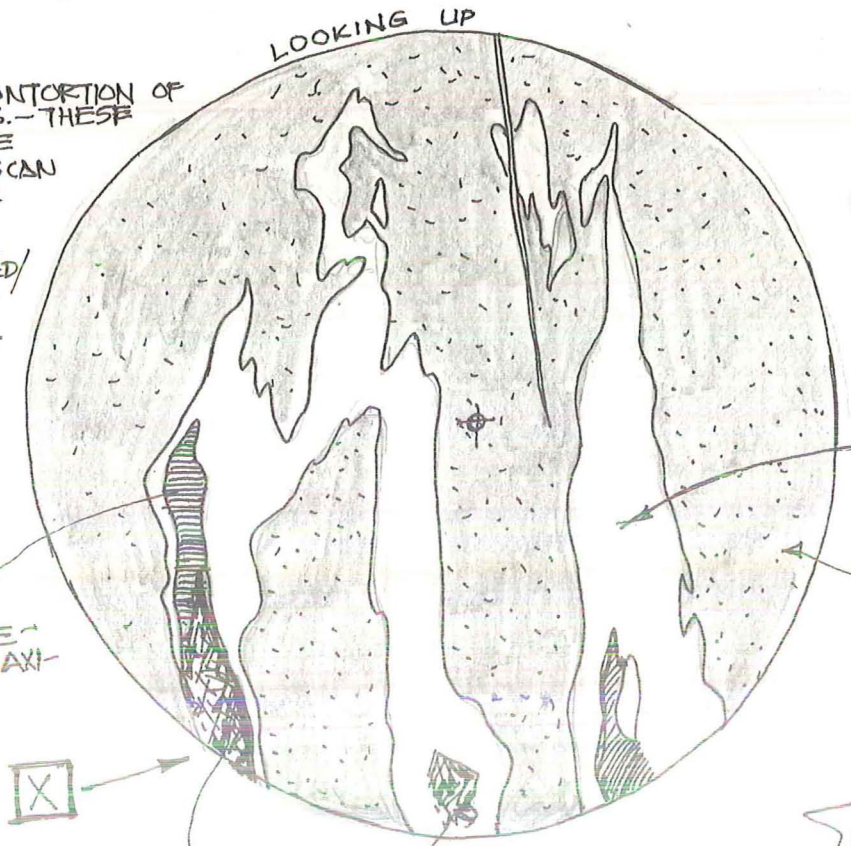
J.B. Hulen
10/06/90

(#3) This is not your worst nightmare. It's a view ⊥ to the core axis (looking down) at about 8531.5' (SCHEMATIC)

XI

This really looks like metamorphically modified "ball-and-pillow" and other load structures.

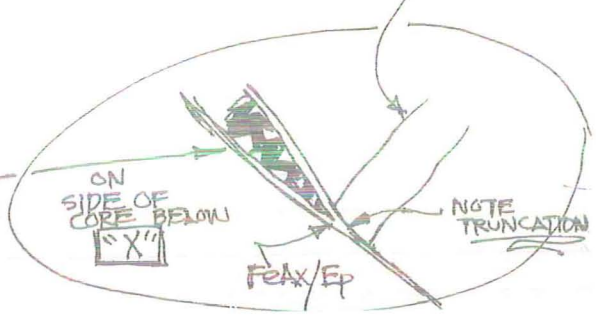
rock type exerts strong control on fracture/vein intensity.



NOTE CONTORTION OF QTZ VNS.—THESE MUST BE FRANCISCAN VINTAGE WITH CALCITE DISSOLVED/REPLACED WITH EPIDOTE & FERROAXINITE.

(#4) @ 8939.20'
LOOKING UP ALONG CORE AXIS

XI



RECONNAISSANCE NOTES

Sample Identification	Petrographer/Date of Examination
OF 27A-2 10,373'	J. HULEN 09/23/90

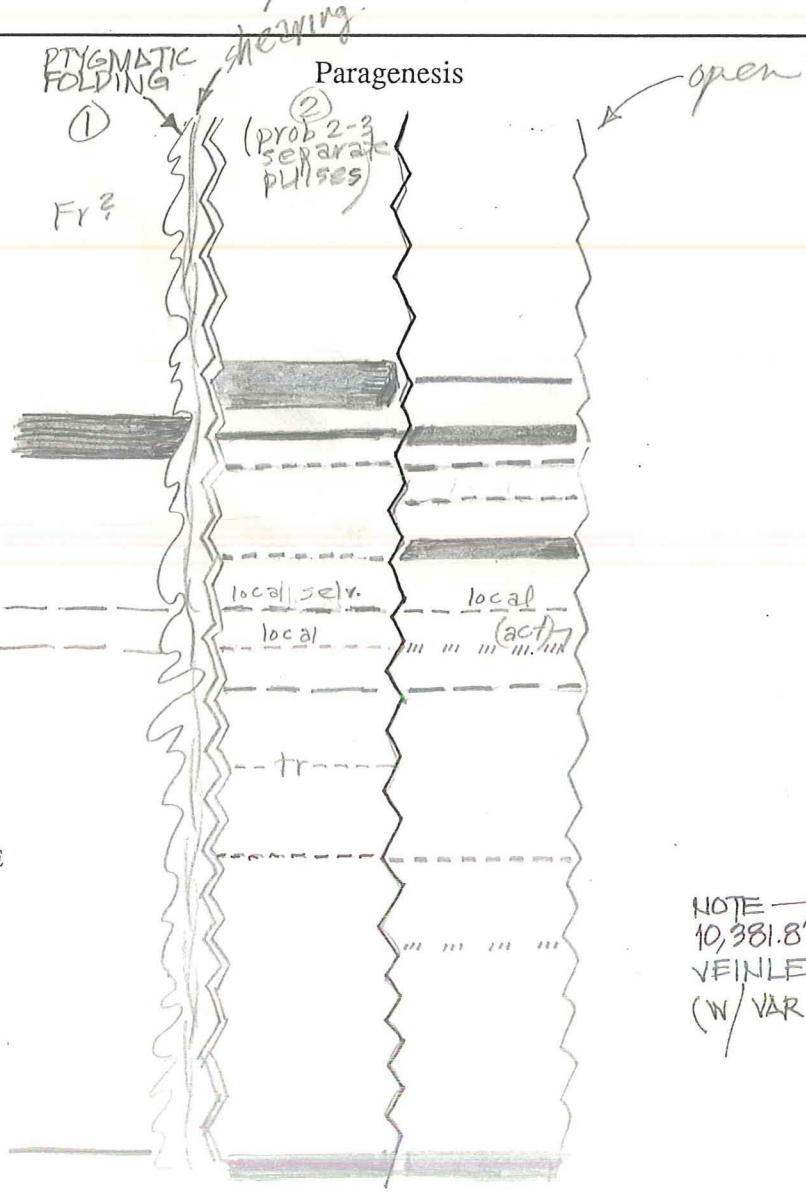
Rock Type hornfelsic sandy argillite & lithic metagraywacke, tectonically intermixed, then contact-metamorphosed, heavily veined

Fracturing/Brecciation/Veining and Vug-Filling ; heavily-veined — est 7% TRV; early (Fr?) veins commonly ptygmatically folded.

Alteration/Metamorphism
conversion of much of the early phyllosilicates (ill + chl) to biotite ± brown phengite.

Fluid Inclusions
abund in stage ③ vn/ls <1-10μ, mostly irreg., some neg. xl.-shapes; dom. vap-rich, some liq.-rich w/ L:V ≈ 3/1 (>260°C Th).

Porosity Summary est < 0.5% TR Φ; most as late, open vfractures, some intercrystalline Φ in veinlets



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UNOCAL GEOTHERMAL DIVISION

Well:
Field:
Drilling fluid:

State:
County:
Location:

Date: 5-FEB-1990
TTCS File #: 5030
Elevation:

FULL DIAMETER DEAN-STARK ANALYSIS

Sample Number		Porosity %	Saturation Oil %	Saturation H2O %	Grain Density (gm/cc)
1	NEGU-17 A	1.6	0.0	13.5	2.71
2	NEGU-17 B	3.8	0.0	4.4	2.70
3	NEGU-17 C	4.5	0.0	7.2	2.71
4	NEGU-17 D	1.4	0.0	26.0	2.72

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Field:
Drilling fluid:

State:
County:
Location:

Date: 5-FEB-1990
TTCS File #: 503052
Elevation:

2-INCH PLUG POROSITY AND GRAIN DENSITY

Sample Number		Porosity %	Grain Density (gm/cc)
1	NEGU-17 A	0.8	2.70
2	NEGU-17 B	1.2	2.71
3	NEGU-17 C	4.0	2.71
4	NEGU-17 D	1.9	2.74

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Well:	State:	Date:	5-FEB-1990
Field:	County:	TTCS File #:	5030S2
Drilling fluid:	Location:	Elevation:	

1-INCH PLUG POROSITY AND GRAIN DENSITY
OVERBURDEN PERMEABILITY (8000 PSI NET EFFECTIVE STRESS)

Sample Number		Permeability Horz (nd)	Porosity %	Grain Density (gm/cc)
1	NEGU-17 A	81.9	1.3	2.71
2	NEGU-17 B	103.8	1.1	2.70
3	NEGU-17 C		5.6	2.73
4	NEGU-17 D		2.3	2.76

RECONNAISSANCE NOTES

GRAPHIC LOGS

DEPTH	ALTERATION (WMS)	FRACTURING (WMS)	VEINING & VUG-FILLING (WMS)	VEINLET & VUG-FILLING PHASES (QTZ, KFSP, BTE, TOUR, CHL, PY)	GRAPHIC GEOLOGY	NOTES, COMMENTS	DESCRIPTIONS
10,369							Hornfelsic, lithic MGW, med-dk. grayish-brown, heavily veined (at least 2 diff. generations (see ★1)); rubblized, rubble pcs. coated w/ lt. grayish-red film.
beg. 10,369.5' 1★						RUBBLE	
70							
						crudely slickensided FRX w/ qtz dip 85°	HF MGRW, as above, w/ steeply-dipping crudely slickensided fracture; RX is heavily veined, same as above w/ local "jigsaw-puzzle" breccias cemented with tourmaline & qtz. & kfsp.
71						rubble	
						MAJ VNLT TOURM DIP n 25°	RICH
							Possible pebble bx, but diff. to say since matrix was a ybx already. Could also be Franciscan-vintage intermd bxtn, but lean toward the former hypoth.
						★Rubble. Frac. dip 85-90 (3★)	Argillaceous hnflsc. MGW prominent shear-enhanced bedding, v. strong qtz-tour. veined many veins appear deformed/ amoeboid.
10,373 2★ 3★							
							now just rubble — apparently once intact — same rock as above, intricately stkwk-veined w/ qtz-TOUR-KF-BTE in various combinations. locally prominent "jigsaw-puzzle" textures, suggesting hydraulic fracturing. — many fragment surfaces bound by the crudely slickensided tectonic fracture noted above; a few of the frx are coated w/ qtz, chl & scattered pyrite.
74						NOTE NO VUGS	
75						TAKEN FROM McNAMARA '89-90	
76						RUBBLE	
77						TAKEN FROM McNAMARA 1989-90	
						RUBBLE	
						HYDROTH. BX. DIP VERT	jumbled pcs. — not really sure which goes where but rock overall is a dense HNFLSC MGW as above; still sparse, late, high-∠ frx app. coated w/ chl. poss. local scabs of ultra-fine-xln. cubic or pseudo-cubic transp. xl. drusies; also definitely late-stage chl-qtz-py VNLTS.
78							
						RUBBLE	
10379							

LOOKING ⊥ TO FRX (hi-∠) SLIX

crude slix

DRILL HOLE OF 27A-2

LOCATION

LOGGED BY J. HULEN

10/05/90

"BLEACHING" RETROGRADE ALTN. TO QTZ-CHL-(EP?)-(KF?)

RECONNAISSANCE NOTES

GRAPHIC LOGS

DEPTH

ALTERATION: WMS | WMS | WMS | QTZ-CHL-(EP?)-(KF?) WMS

FRACTURING: WMS

VEINING & VUG-FILLING: WMS

VEINLET & VUG-FILLING PHASES: QTZ | PY | BTE | PRRH. | TOURC | BN | CPY | CHL | EP | KF

GRAPHIC GEOLOGY

NOTES, COMMENTS

DESCRIPTIONS

10379

RUBBLE

Note:

380

Note: in the 2' core below, there are numerous pitty open frx mostly dipping ∠15°; a few // "bedding" (N40°) (avg. spacing 0.5/cm)

RUBBLE

381

2' solid core section — v. prom., steeply-dipping hydroth. bx. vein to @ 10,381.8'. — sulfide-poor

HYDROTH. BX

*5

these could be artifacts of the drilling process.

382

*6

Appearance of sulfide-rich qtz-chl-(ep?) vnlts at @ 10,381.8' → these increase downhole; they contain both bornite and chalcopyrite; many are sub-parallel, dip >75°

HIGH-% SULFIDE RICH VNLTS

383

THIS LOOKS LIKE PORPHYRY-COPPER ROCK !!

RUBBLE

INTENSELY stkwk vnd. HNFLS. ARGILLITE & Metagrw. (now rubblized); originally med-dk. grayish-brown, widely retrograde altered to QTZ-CHL-(KF?)-(EP?)-SULFIDES, including PYRITE, PYRRHOTITE, CHALCOPYRITE, BORNITE (tr.); est TOTAL sulfides @ 2%; %Cu 0.07-0.10% (below

- sulfide-rich clots in the centers of some QTZ-CHL-EP(?)-sulfide veinlets are up to 3 mm. wide, vns up to 4 mm. wide w/ selvages up to 4X vein width; prominent "bleached" effect where veins coincide.
- The sulfide-rich veinlets break readily, and are responsible for the intense rubblization below 10,383 ft. (the veinlets, by contrast w/those formed earlier, are not "frozen" to the veinlet walls).
- In a few rubble chunks — looks like there's a late-stage pyrrhotite veining event which cross-cuts QTZ-PY-(BN?)-CPY veinlets

384

√ T.S. 10,383')

DRILL HOLE OF 27A-2

LOCATION

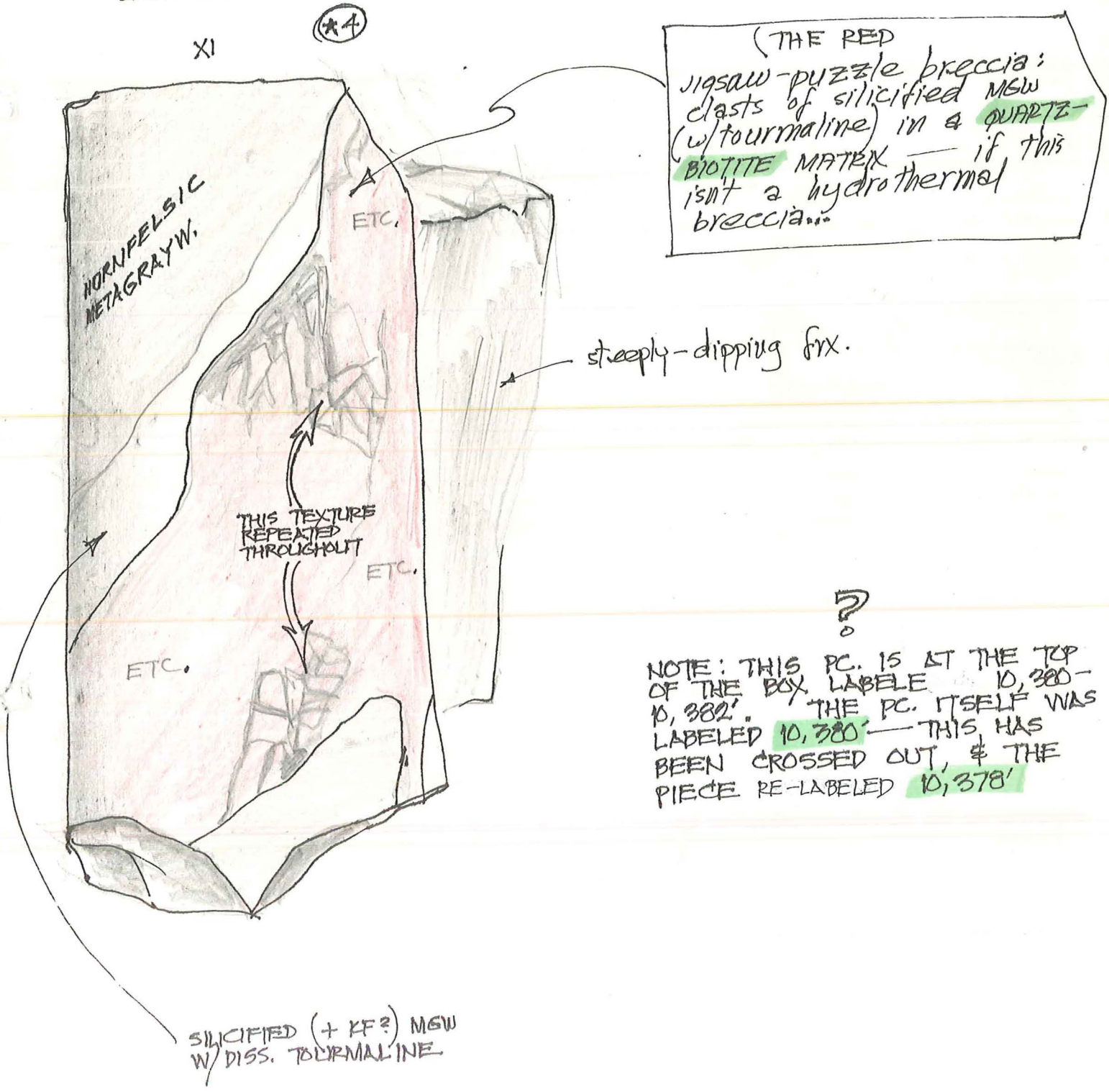
LOGGED BY J. HULEN

10/05/90

OF-27A-2

Reconn. Notes

10/05/90
Jeff Hulen



SCHEMATIC SIMPLIFIED

see next page

OF-27A-2

2' cont. core

RECONNAISSANCE NOTES

J. HULEN 10/05/90

#5

CONTINUED

~ 10,381.8'

w/ erd shape reflects ∠ of intersection with core

VEIN QTZ-TOURM-KF-BTE

sheared-appearing, but shearing seems largely to have pre-dated brecciation & qtz-tourm-kf-bte veining.

Lat. frx coated w/ ep (?) qtz, chl.

stockwork-fractured hmfl sc. MGW, "bleached" in part from normal med-dk. grayish-brn to a lt-med. slightly greenish-gray (suspect this could be potassium silicate + qtz + minor chl. altn. adjacent to veins.

QTZ-TOURMALINE-KF-BTE ALT.—FLOODED ROCK FLOUR with scattered, fairly small (< 10 mm dia.) clasts. this is almost certainly a hydrothermal breccia dike/vein — note gradation outward into "jig-saw-puzzle" breccia then stockwork fracturing (a continuum) bte seems mostly to post-date tourmaline.

UP

~ 10,381'

RECONNAISSANCE NOTES J. Hulen 10/05/90

OF 27A-2

(#1) Rx. is hornfelsic lithic MGW, med.-gr., dense, med-dk. grayish-brown due to high bte. content; Rubblized, w/ pcs. ranging from <1 mm to 7.5 x 5 x 2 cm (avg. w 15 mm. max diameter) The fractures bounding the chunks are apparently random in orientation w/ slight bias toward higher ∠'s (>70°); many of these fractures are re-broken along earlier veinlets; a few are! — ~~seem to be~~ crudely polished & slickensided (tectonic origin — for the frx, not necessarily the veinlets; some of the fracture surfaces have a faintly salty taste

Rx is heavily stockwork-veined, again apparently random orientation w/ qtz-ksp-tourm-chl ± fr ilm.enite(?) in various combinations — paragenesis ambiguous* in these chunks. vns. range from hairline wvnlts to 3 mm. in width avg w 0.5-1 mm — some crudely banded.
* but probably 2 generations.

(#2)

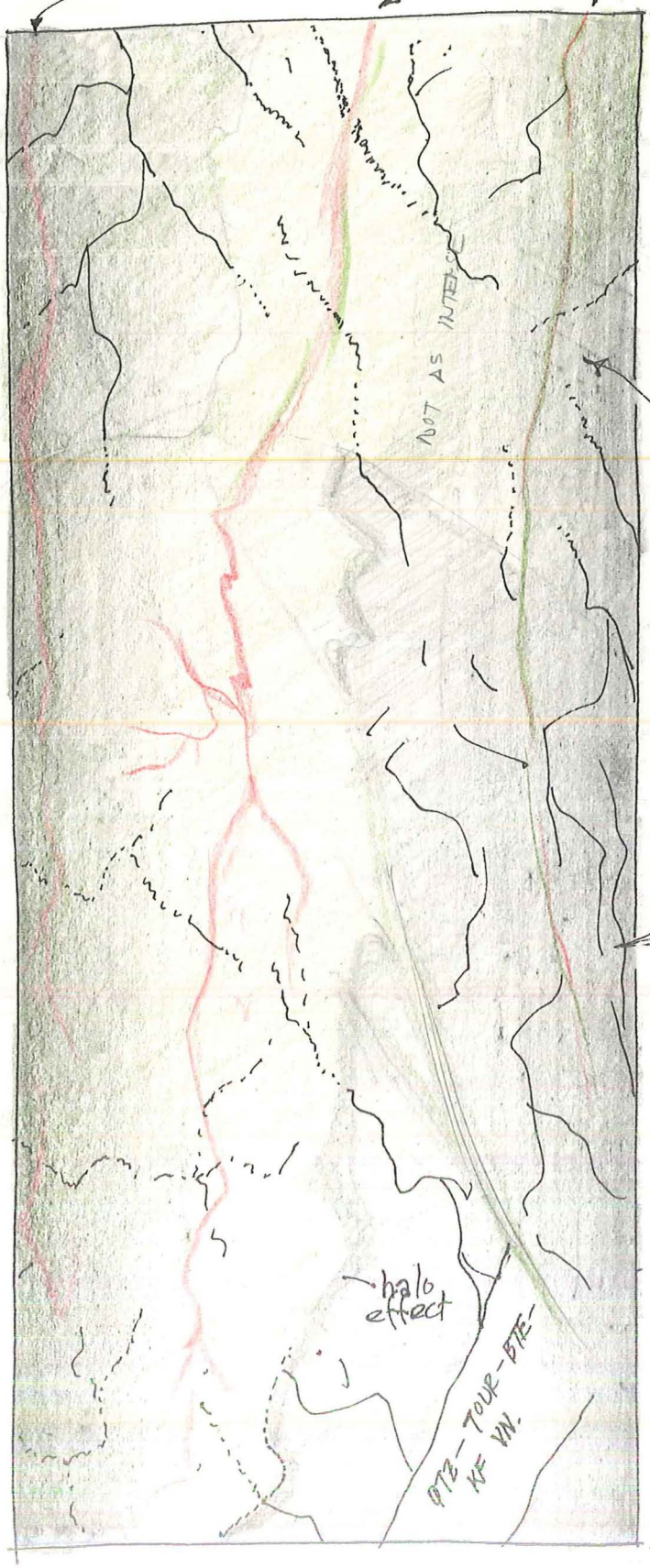
(red) QTZ-TOUR-(KF?) veins/masses — this particular one looks like it's been metamorphically "rolled"

← 10,373

sheared (met) argillaceous HNFLSC MGW w/ strong argillaceous interlaminations — v. intense & texturally unusual, QTZ-KF(?) TOUR. veining which looks metamorphically deformed.

* - the steeply-dipping fracture cutting the above core is apparently sparsely coated w/ tiny clear euhedral x/s.

WATER DAMAGE



6F 27A-2

RECONN. NOTES

J. HULEN 10/05/90.

~ 10,382.6'

*6

THE SULFIDES INCLUDE CPY & BORNITE

late qtz-chl-ep-sulfide veinlets up to 4 mm. wide (apparent) dominantly steeply-dipping — these conduits apparently responsible for the greenish "bleaching" (retrograde altn.) the sulfides extensively altered to hematite at the core surface.

retrograde altn., "bleached"-appearing, dense, lt-med. greenish-gray — suspect qtz-kf(?)-ep-chl. "flooding" (look for XPD piece)

see below.

DOWN

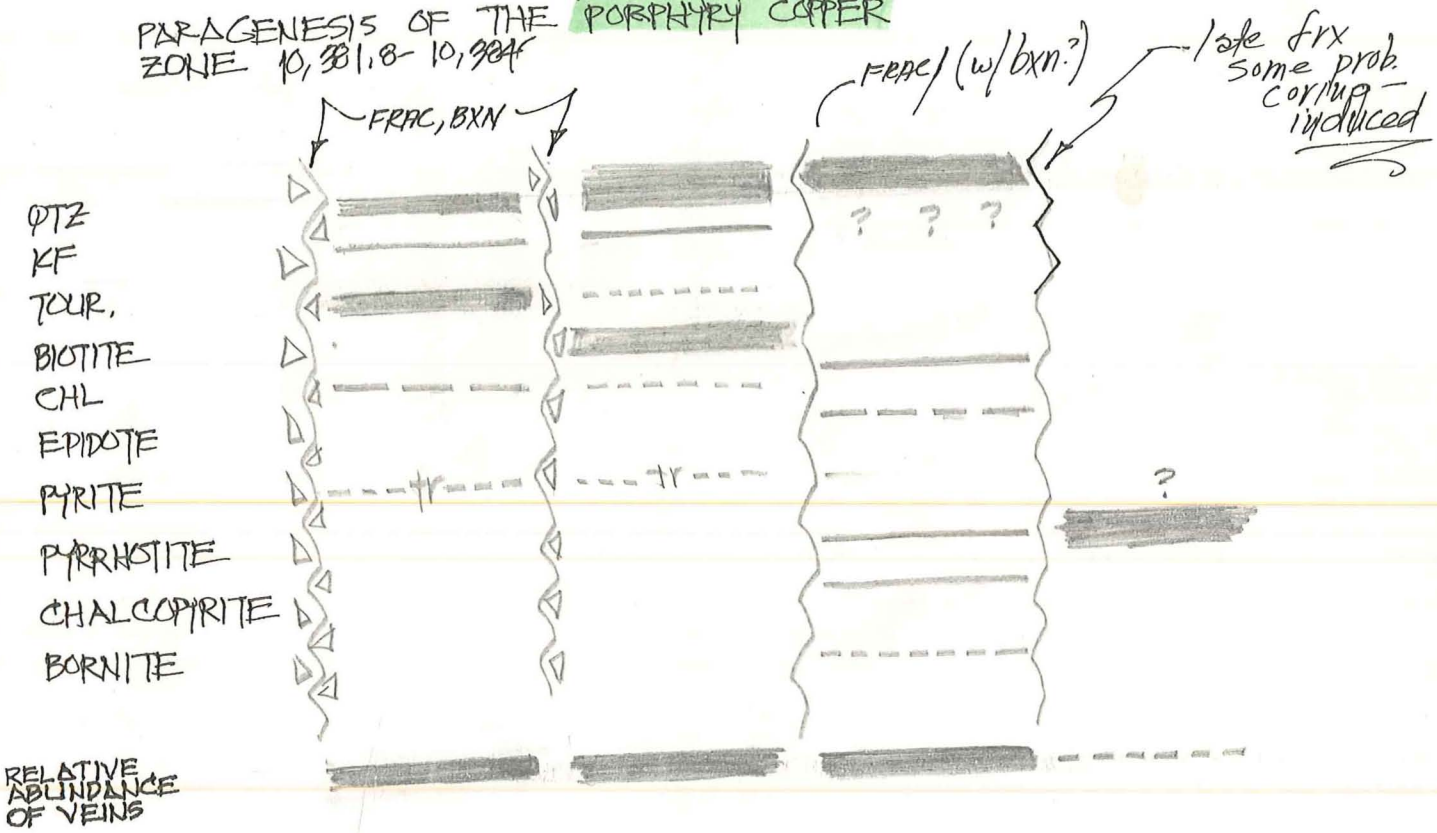
SCHEMATIC

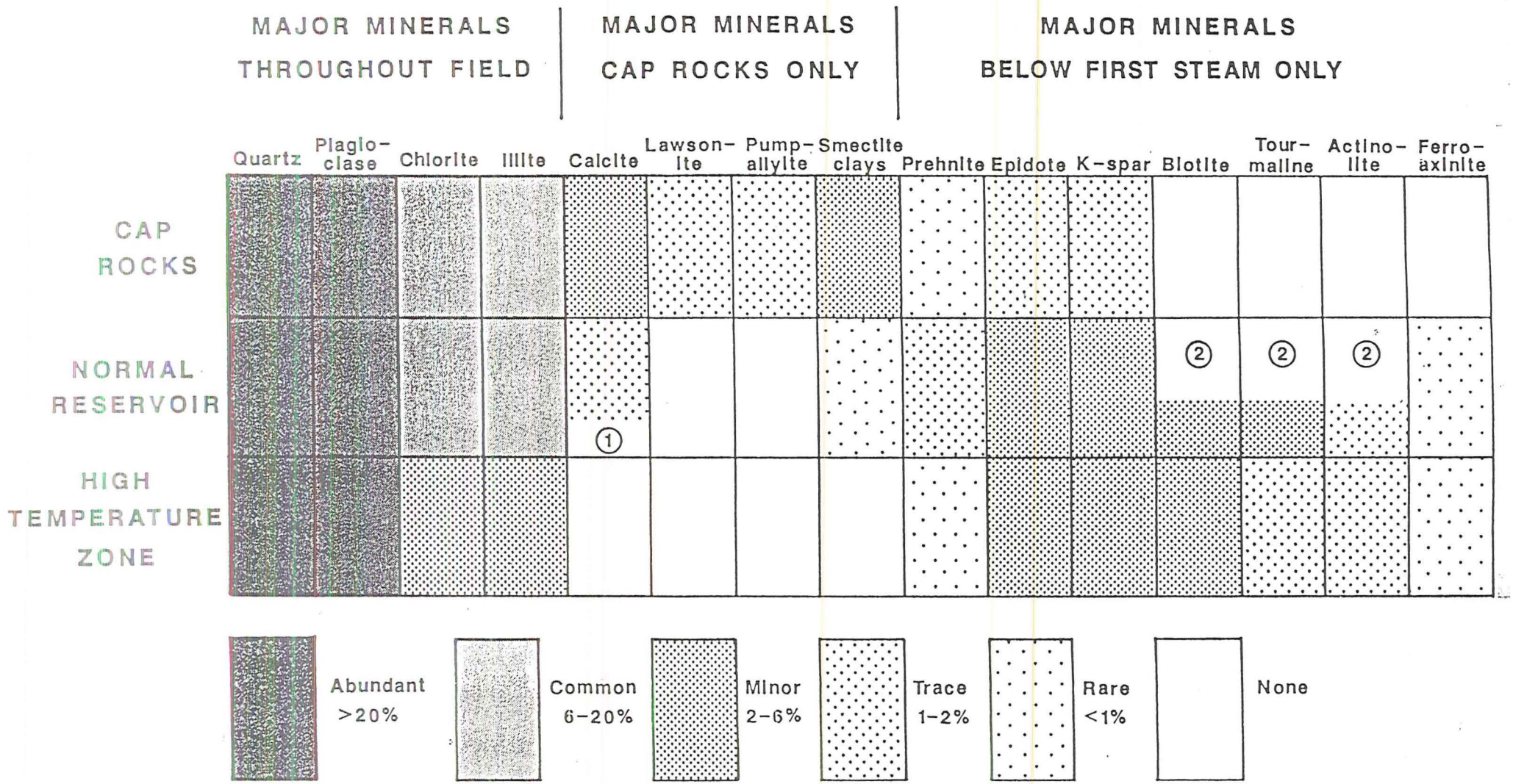
~ 10,381.8'

RECONNAISSANCE NOTES
J. Hulen 10/05/90

OF 27A-2

PARAGENESIS OF THE "PORPHYRY COPPER" ZONE 10,381.8 - 10,984'





R.C.T. 10/88
UCA20.2422

Figure 2. Distribution of major minerals at The Geysers.

Franc. qtz

Fvarnal qtz-cal

Ab-ep

ΦTz-Ep-KF-chl-(zoi?)

KF-Φ-Ep

KF-Φ

KF-FeAx

KF—Ep

Prati 32

FeAx (Φ)

Ep (Φ)

Ep-Chl-qtz-KFsp

KF-FeAx-ΦTz

FeAx-Ep (Φ)

KF-ep-ΦTz-BTE-SP

~~Ep~~ Φ-KF-PR-ep-SP
(preferite replacies)
epidote

Prati 32
8010-8010'

Fqtz-cal

Ab-ep
qtz

KF

qtz
chl-ep
leucox

Fr [Qtz-Sch]

Prof 1 - 32
8050-8060'

Q - Act - Cpxn - ep - ilm.

KF - Act - Leucoxn

Q - Act - Ep.

Act - QTZ.

KF - Chl - Leucoxn

Ep - qtz - KF

Ep - qtz - chl - leucoxn.

(Ep)

* FeAx - Actinolite

FeAx - Qtz - Ep - KF

FeAx - Qtz - KFsp - ilm - leuc.

FeAx - tourm.

tour. replaces FeAx

QTZ-BIE-PO-ep
yahoo!

brown phengite

KF-ep-leuc-gtz

Practi-32
8100-8110

chl-act-KF-ep-gtz
ep-act - gtz - bu(?)
act-KF gtz ± leuc.
act-KF-ep-leuc-ser

FeAx-act-ep-gtz
(Feax engulfs act & ep & gtz)

chl-gtz-kfsp-cel (bladed)

8150-8160

ep-act-leucoxn
ep-act-gtz-kf-(leuc)

cel (F?)

ep-g-kf-(leuc)
KF-gtz

Pract-32

8200-8210'

ACT-EP-KF-ϕTz-CH-leuc/il/m EP KF

ACT-EP ϕTz KF-ϕ-Ep

KF-ϕ-ILM

FeAx-Act-Ep-ϕ-(KF)-(ilm)

FeAx-Ep

FeAx-Act-ϕ-Ep-KFSp

---

encapsulated

KF-ϕTz-Cal

KF-Chl

KF-ϕTz

8250-8260

dominantly by itself

FeAx

FeAx-(8)-(act)

mostly small paths porous

ϕ-Ep-Kf-(Bte)

Pr

ACT-Chl-ϕTz-KF Ep-ϕTz

~~Act~~

~~ACT-ϕTz~~

8300-8310'

FeAx-Act

FeAx-Ep-ϕ

FeAx-KF

ϕ-Act-KFSp

Act

Act-ϕTz.

KF

KF-ϕ

hydroth.
10/3 ← Franciscan

Hydroth

bleeked cel		% TL VN MINERALS	Fr QTZ	QTZ	KF	AB	Fr. CAL/C.	EP	PR	ACT	FeAX	SPHENE/LEUC.	CHL	BTE	Fr CHL	TOUR.	cpy bn	PY	SP	PD
(14)	8000 – 8010	18	4	2	6	Tr	Tr	3	Tr	Tr	2	Tr	1	Tr	Tr				Tr.	
(8)	8050 – 8060	11	2	1	3	–	–	1	–	2	1	Tr	Tr	Tr	1/1	Tr		TR		Tr
(8) Tr	8100 – 8110'	13	2	1	3	–	Tr 1	1	Tr	2	1	Tr	Tr	1	1/1	Tr	Tr	Tr	Tr	
(7)	8150 – 8160'	8	1	1	2		Tr	1	–	2	1	Tr	Tr		Tr/Tr			Tr		
(13)	8200 – 8210'	14	1	1	3	–	–	5	–	3	1	Tr	Tr							
(11)	8250 – 8260'	13	2?	2	2		1	2	Tr	1	5	Tr	Tr	Tr	?			Tr		
(7)	8300 – 8310'	9	2?	1	2		Tr	1	Tr?	1	2	Tr	Tr	–	Tr					
	8350 – 8360'		2?	1	3		–	2		1	4	Tr	Tr							
	8360 – 8370'																			
	8370 – 8380'																			
(14)	8380 – 8390'		?	2	3		Tr	3		1	5		Tr							
	8390 – 8400'																			
	8400 – 8410'																			
	8410 – 8420'						Tr.	3		2	2									
	8420 – 8430'		*	42	2		Tr	2		2	3	Tr	Tr	Tr?	–					
	8430 – 8440'																			
	8440 – 8450'																			
	8500 – 8510'																			
	8550 – 8560'																			
	8610 – 8620'																			
	8650 – 8660'																			
	8710 – 8720'																			
	8750 – 8760'																			
	8790 – 8800'																			
	8850 – 8860'																			
	8890 – 8900'																			
	8950 – 8960'																			
	8990 – 9000'																			
	9050 – 9060'																			
	9090 – 9100'																			

most pkc prob. mod.

PRATT-31 EST. % VEIN MINERALS