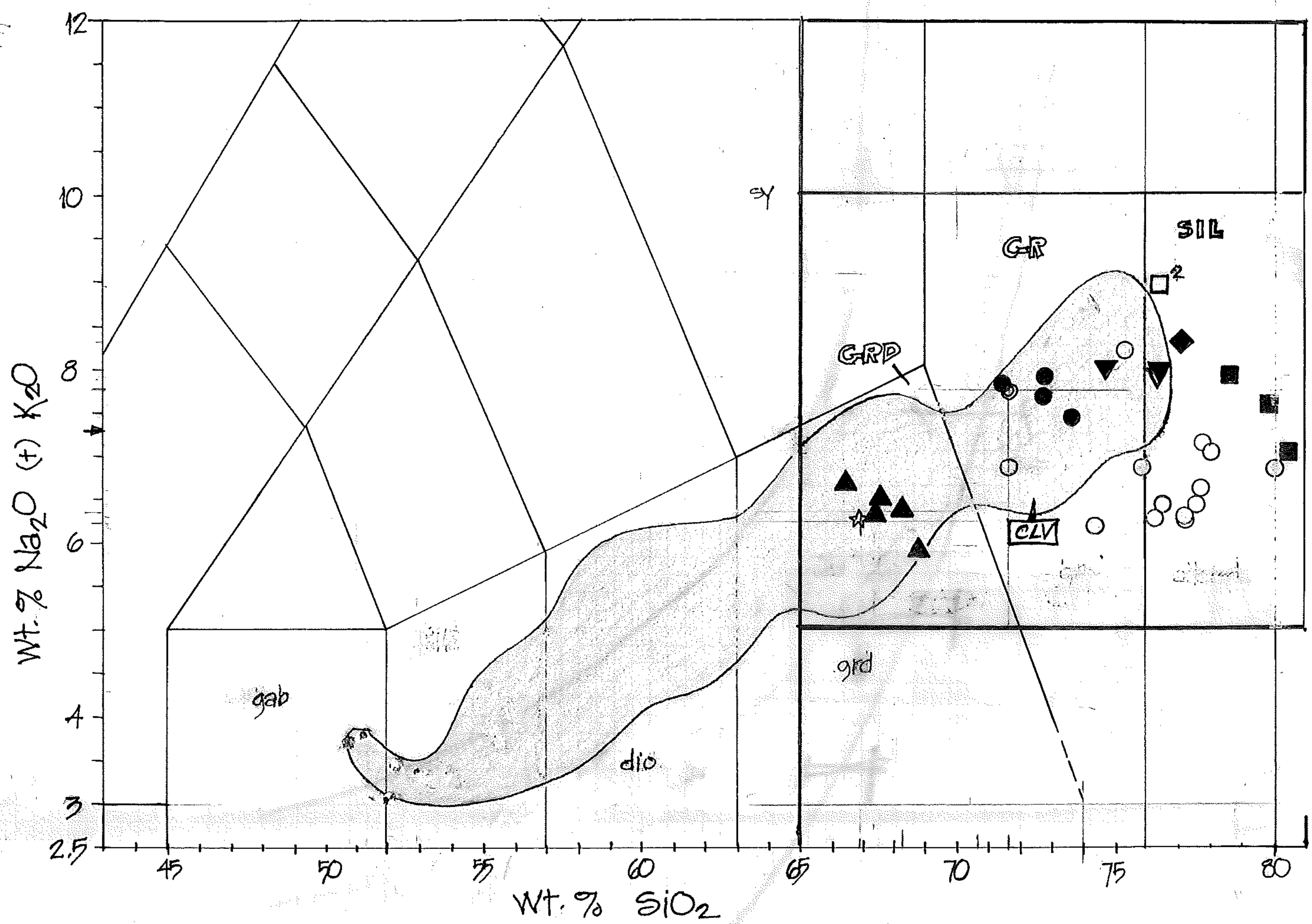
96.78 99.47 0.13
1.77 96.82

GL04333



☆ DCY
◎ RAC

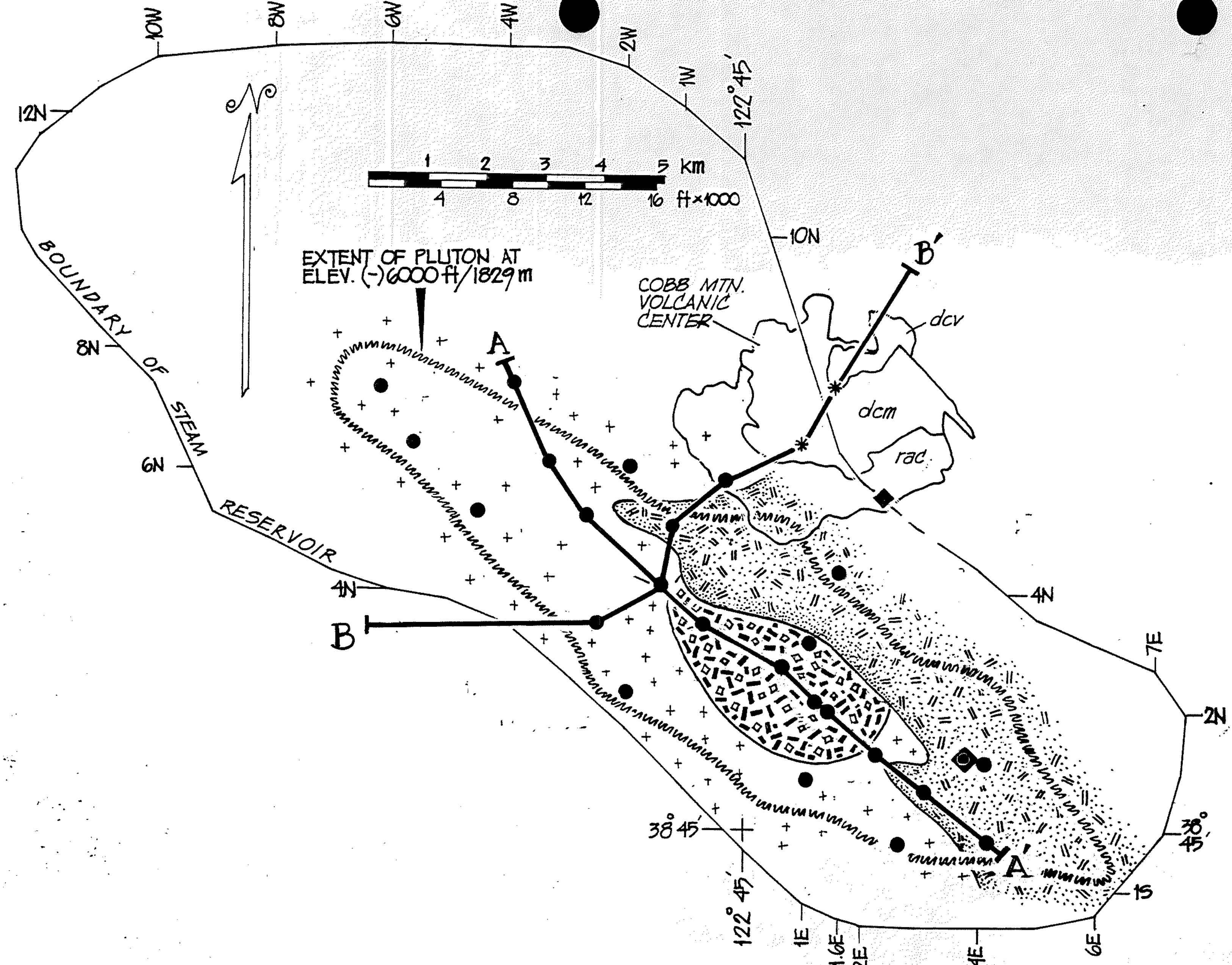
○ Granite[1,5]
▲ Granodiorite well CA-958-6
● Granite porphyry, well GDC-21
■ Microgranite porphyry, well DV-2
◆ Granite porphyry, well C-11
▼ Granite porphyry, well LF-48
□ Rhyolite porphyry dike[1]
~~■ Average metagraywacke, Sonoma County[2]~~
~~■ Average metagraywacke, Coast Ranges[4]~~
Clear Lake Volcanics[5]

1/ Cuttings; otherwise core except metagraywacke (outcrop)
2/ Schriener and Suemnicht, 1981
3/ Pulka, 1991
4/ Stewart and Pesnick, 1977
5/ Hearn et al., 1981

107

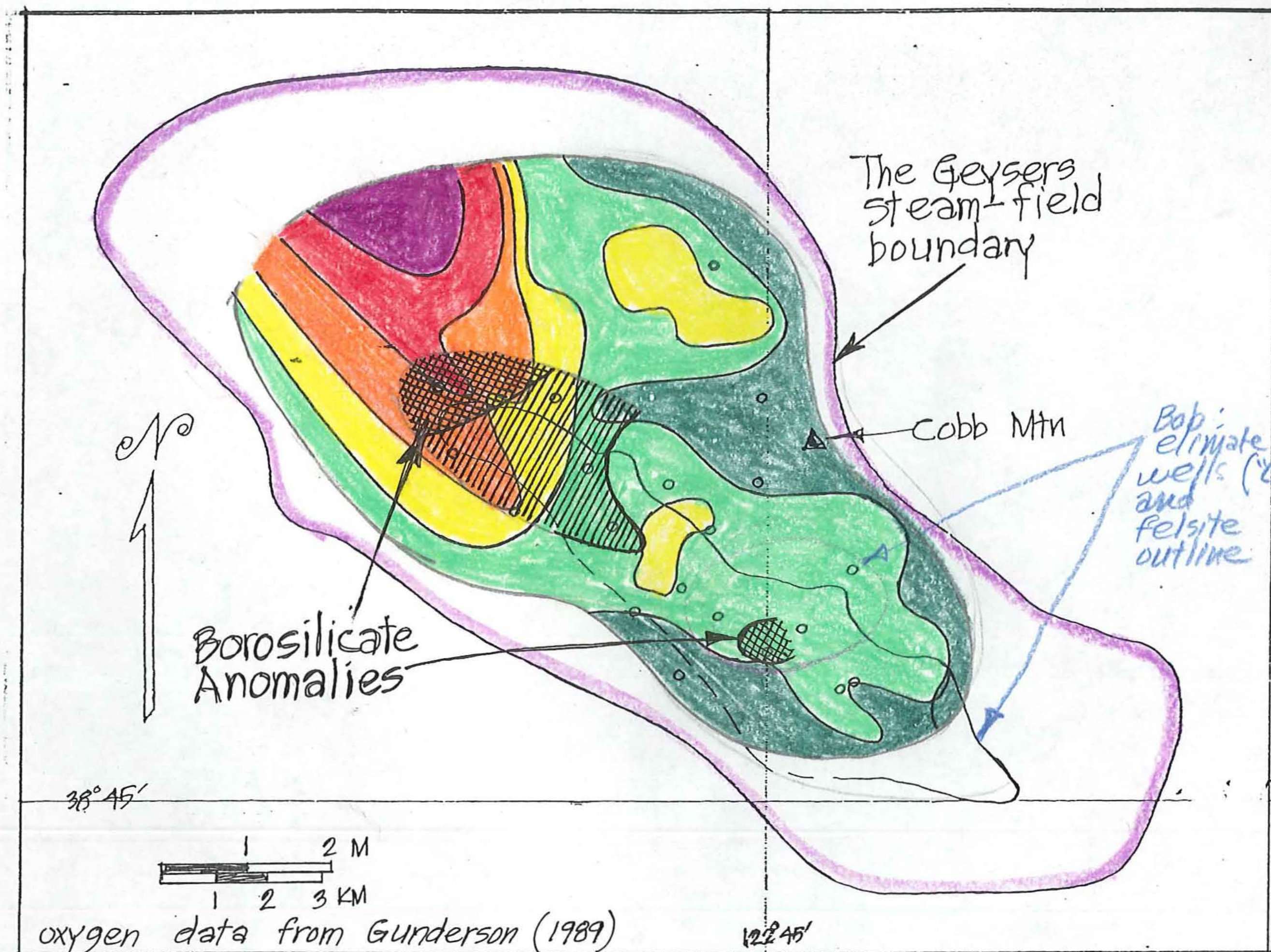
97.71

Figure .



photocopy of JEFFs original

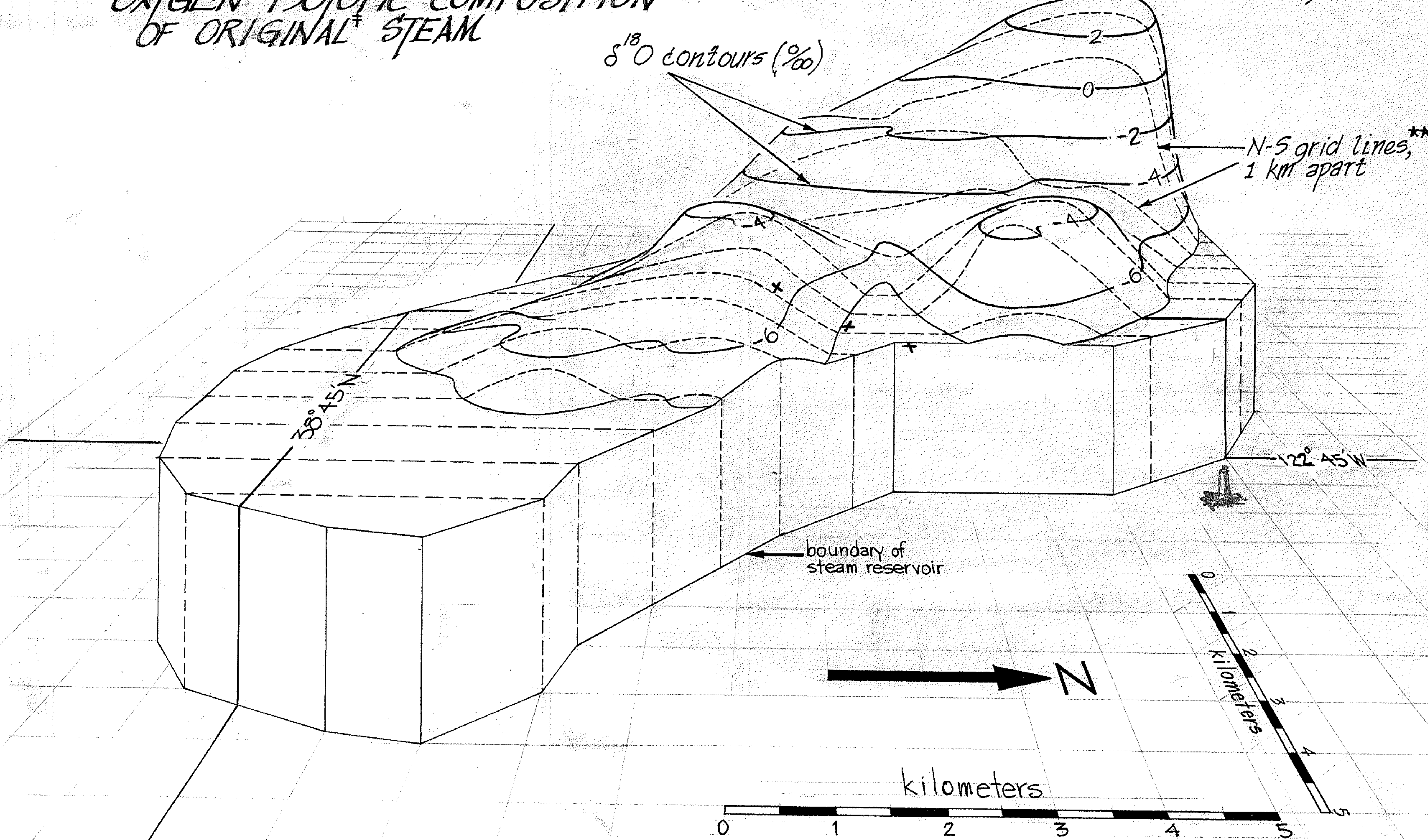
JNM19026.ai



Borosilicate Anomalies vs Oxygen Isotope Values ($\delta^{18}O$, ‰) of "Early" Steam

THE GEYSERS
OXYGEN-ISOTOPIC COMPOSITION
OF ORIGINAL‡ STEAM

(DRAFT)



+ Principal vents of Cobb Mtn. volcanic center, projected vertically to isotopic pseudosurface

‡ Initial production; pre-injection

** Measured east and west from 122° 45'W

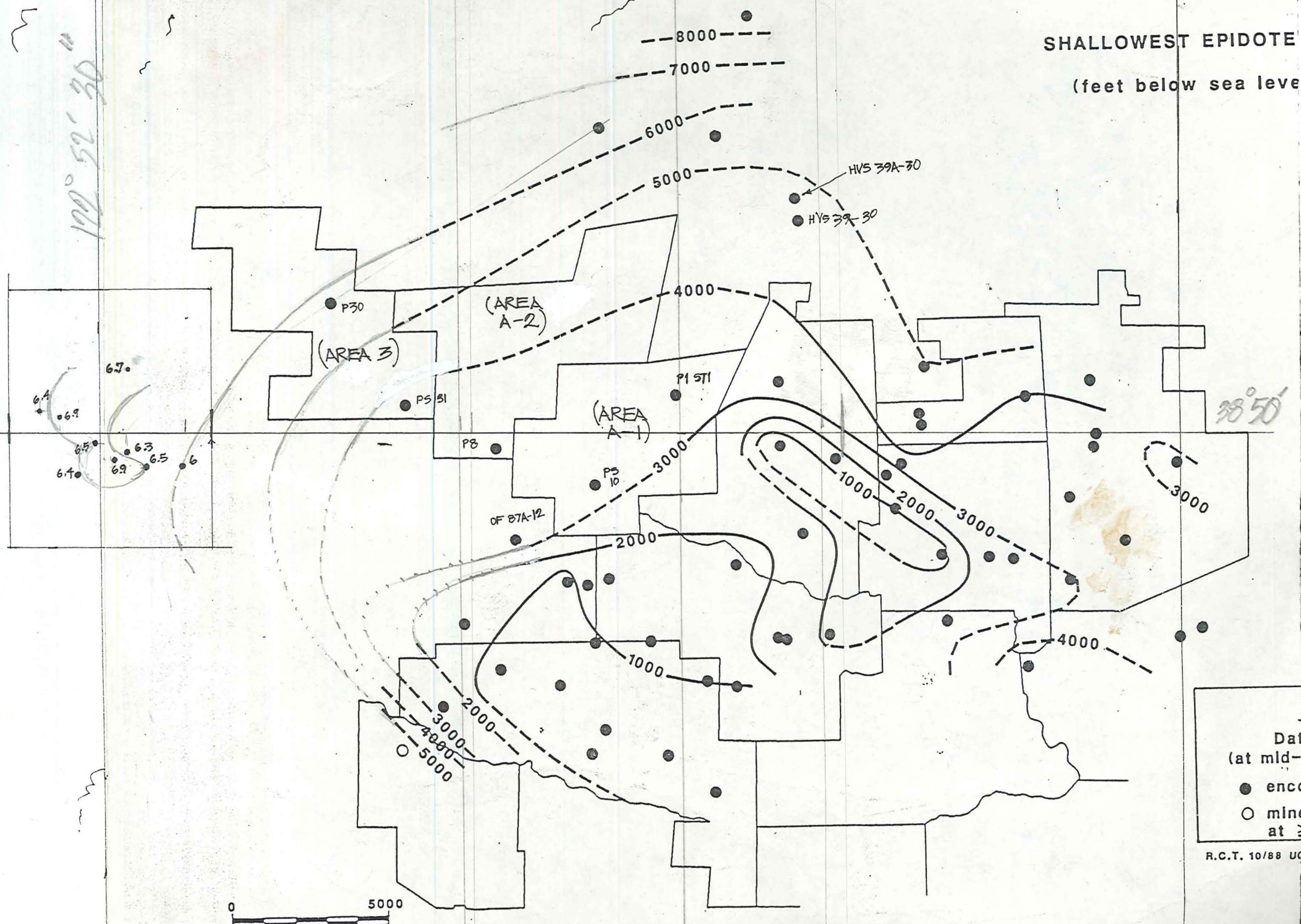
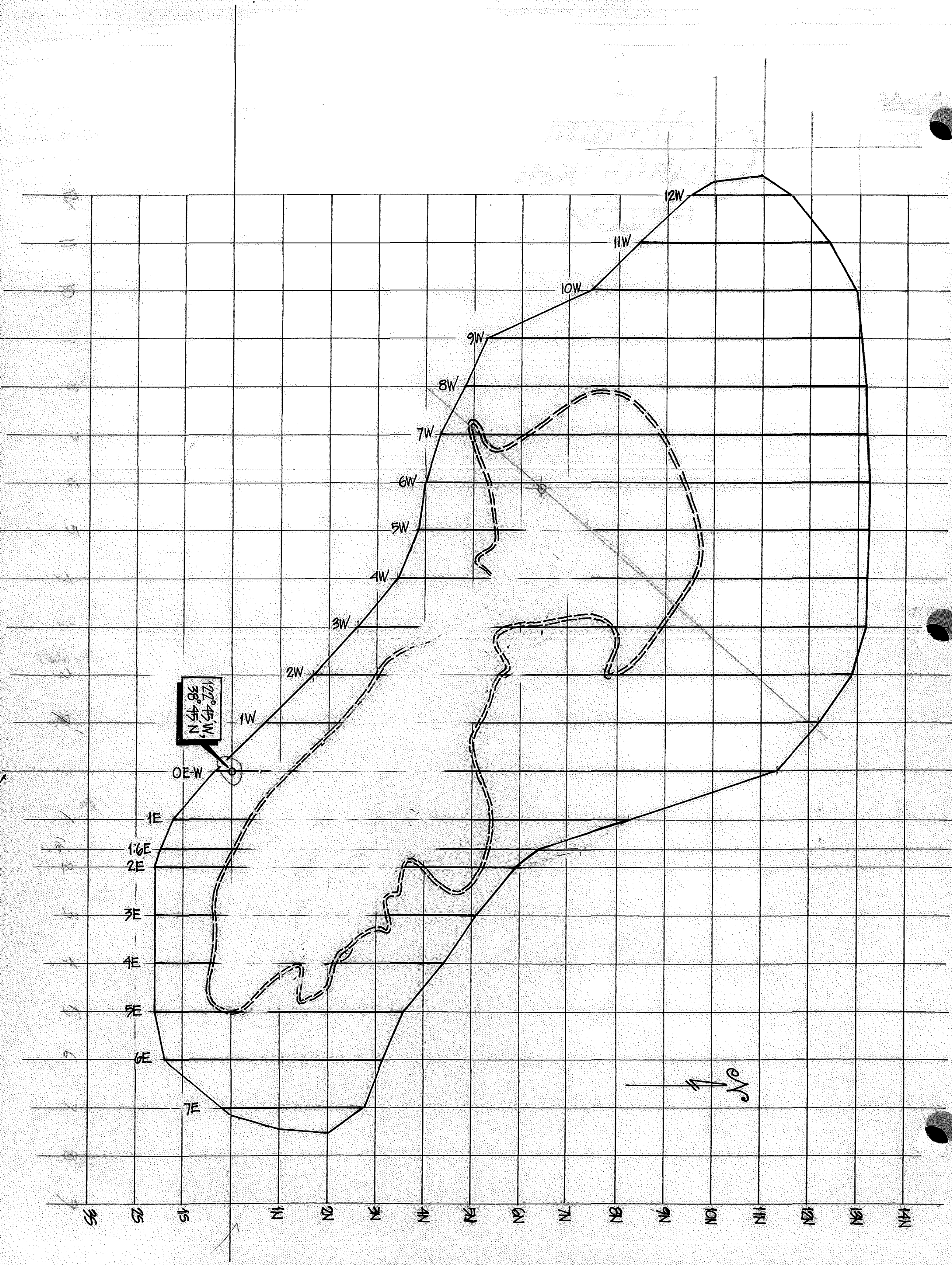
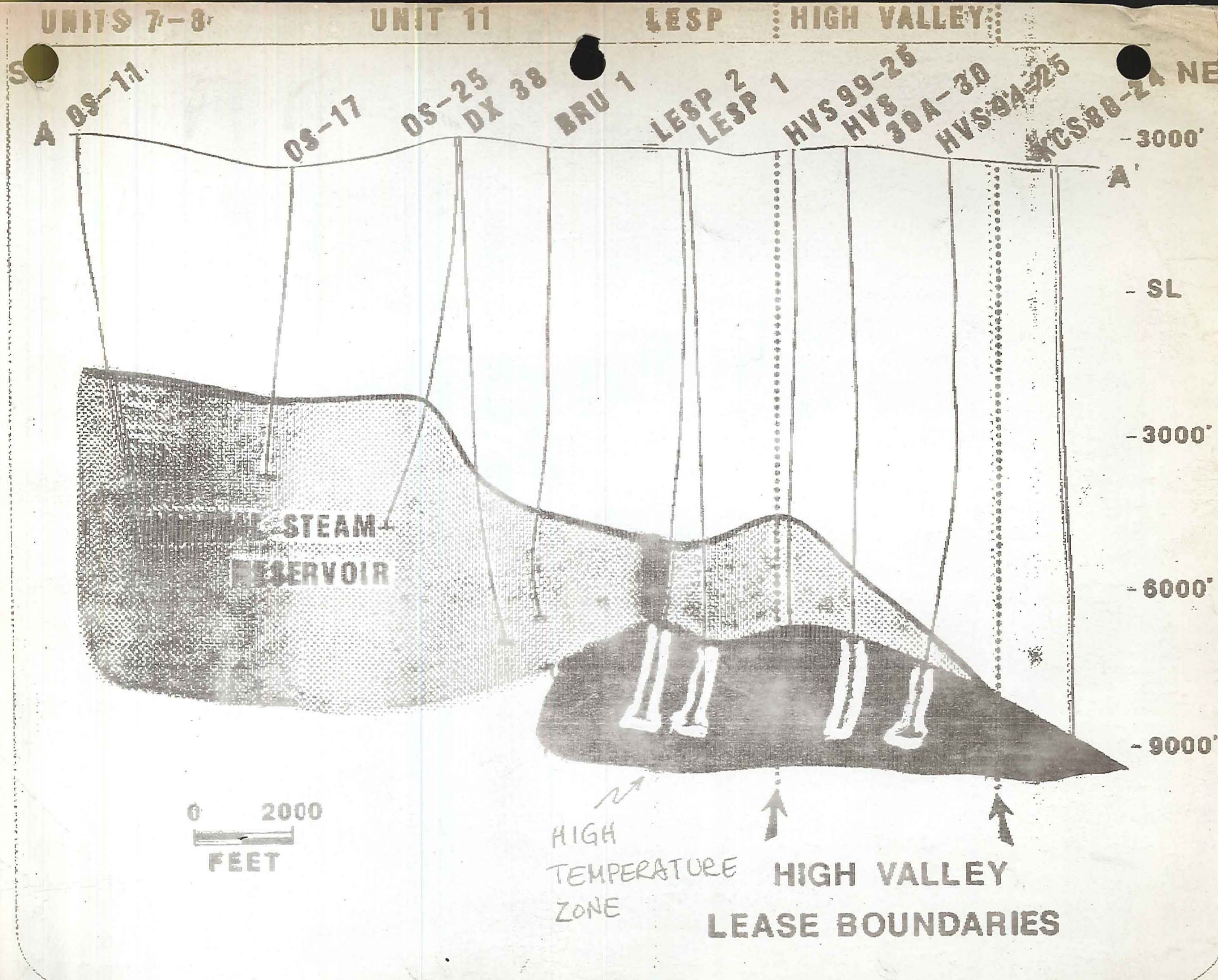


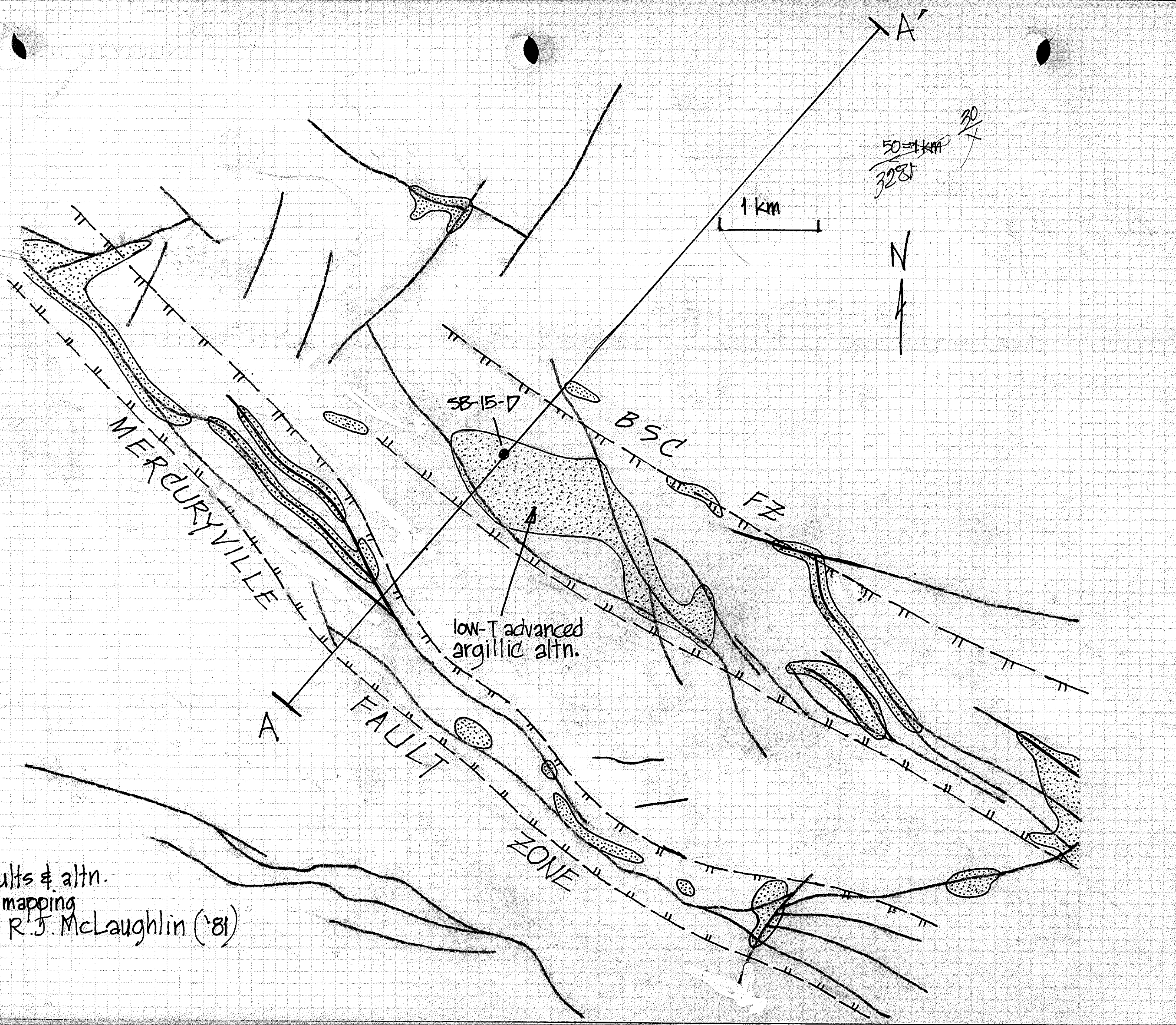
Figure 3. Contour map of the shallowest occurrence of epidote (≥2%).



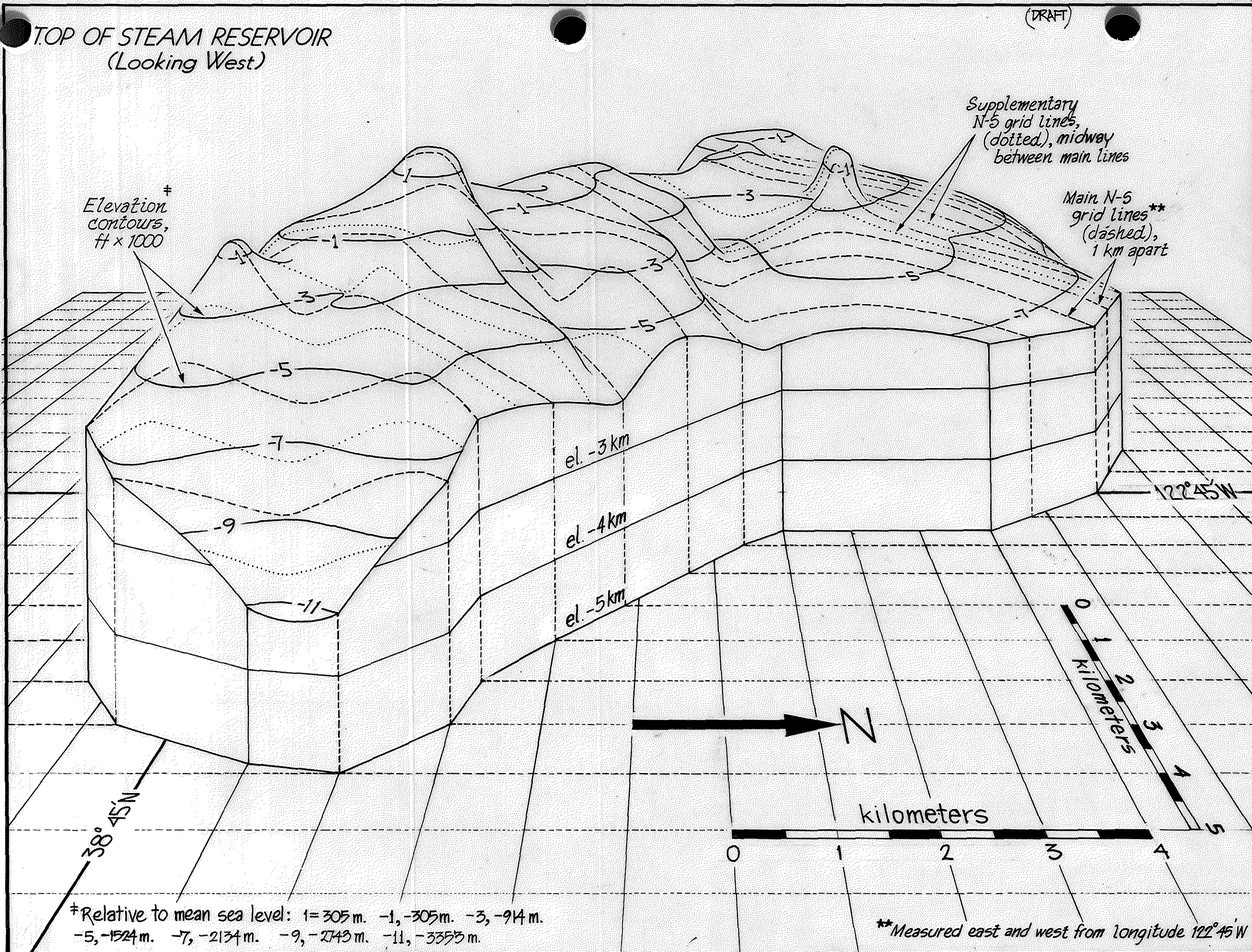
12W
11W
10W
9W
8W
7W
6W
5W
4W
3W
2W
1W
122°45'W,
38°45'N
OE-W
1E
1.6E
2E
3E
4E
5E
6E
7E
3S
2S
1S
1N
2N
3N
4N
5N
6N
7N
8N
9N
10N
11N
12N
13N
14N

FROM UNOCAL S.ROSA 7.15.1991 10:50 P. 3



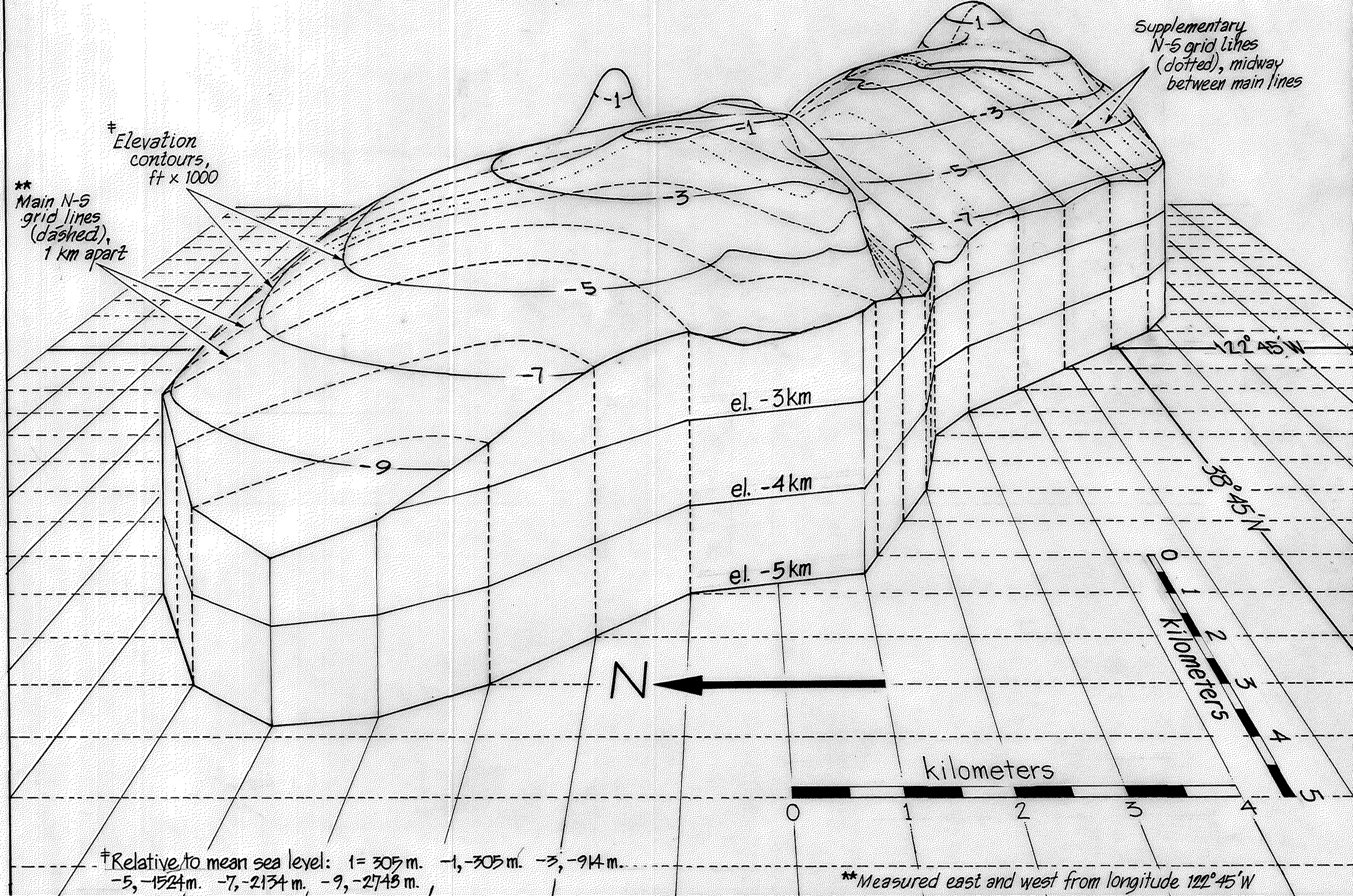


faults & altn.
fr. mapping
by R. J. McLaughlin ('81)


(DRAFT)
TOP OF STEAM RESERVOIR
(Looking West)
Elevation contours, ft × 1000 ‡
Supplementary N-S grid lines, (dotted), midway between main lines
Main N-S grid lines** (dashed), 1 km apart
-1
-3
-5
-7
-9
-11
el. -3 km
el. -4 km
el. -5 km
122°45'W
38°45'N
N
kilometers
0 1 2 3 4 5
kilometers
0 1 2 3 4
‡Relative to mean sea level: 1=305 m. -1, -305 m. -3, -914 m.
-5, -1524 m. -7, -2134 m. -9, -2743 m. -11, -3353 m.
**Measured east and west from longitude 122°45'W

DRAFT

TOP OF STEAM RESERVOIR
(Looking East)



‡Relative to mean sea level: 1 = 305 m. -1, -305 m. -3, -914 m. -5, -1524 m. -7, -2134 m. -9, -2743 m.

**Measured east and west from longitude 122°45'W

Subject: Thermal Prescription
Date: Thu, 24 Feb 2000 14:16:02 -0700
From: "denis l norton" <denis@ruralnetwork.net>
To: "Jeff Hulen" <jhulen@egi.utah.edu>

Thermal Prescription 007:

Prescription for computing the amount of fluid that must be converted to vapor in order to cool a x y z block of rock....

1) the heat in the rock block is mostly in the minerals, small amount in pore fluid, but we ignore that in the following calculation.

2) heat in rock, Qrx = (Volume of Rock)*(density of rock)*(heat capacity rock)*
(Tinitial - Tfinal)
or Qrx = Vrx * Drx * Cprx (Ti - Tf)

eg. 50m cube Vrx = 1.25 10^5 m3 = 1.25 10^11 cm^3

Drx = 2.7g/cm^3 ; Cprx = 0.26 cal/gC

Ti -Tf = 250-235 = 15C

therefore Qrx = 1.32 10^12 cal.

3) heat of vaporization at 100C 1bar 540 cal/g ...
note that at any given pressure/temperature the heat of vaporization can be scaled from LV dome plot in P-H space by picking at the respective pressure or temperature the H value for liquid and vapor the difference between them is Hvap, eg at 200bars Hv = 580cal/g, Hl = 450 cal/g.

Hvap = 580-450 = 130 cal/g

The value you use needs to be consistent with the depth/pressure. because there is a substantial variation in this phase change heat as one moves along the LV surface toward crit point.

4)Heat required by vaporization of fluid in pores.

Qvap = mass fluid * Hv;

eg. for a 2 percent porosity in the matrix block filled with liquid at
a density of 1g/cm3. the total mass in a 50-50-50 block is:
Mass(fluid) = .02 * 1 g/cm3 * 1.25 10^11 cm^3
M(f) = 2.5 10^9 g .

Qvap = M(f) Hv = 2.5 10^9 g * 540 cal/g =1.35 10^12 cal

5)
Because Qrx = 1.32 10^12 cal. and
Qva = 1.35 10^12 cal

the vaporization exactly accounts for cooling the rock by 15C.....

Caveats: note I used values at 100C and 1 bar for Hv, because

Subject: **calculations using Rx**
Date: Fri, 25 Feb 2000 09:13:20 -0700
From: Jeff Hulen <jhulen@egi.utah.edu>
To: denis@ruralnetwork.net

Denis --

I shouldn't be spending time on this, but I'm really curious. Did some calcs to test the concepts. Results for 100 m^3 block cooling from hydrodynamic boiling point temperature, 298C, to vapor-dominated system temperature of 243C:

10^12 cc * 2.7 g/cc * 0.26 cal/gC * 55C = 3.86 * 10^13 cal (heat lost)

Heat required to boil off liquid in same rock block with 2% effective porosity (Qvap at 298C = 341 cal/g)

10^12cc * 1 g/cc * 0.02 * 341 cal/g = 6.82 * 10^12 cal (heat required)

Additional water required to boil to drop rock temperature from 298C to 243C:

3.86 *10^13 / 6.82 * 10^12 = 5.9X

5.9 X 0.02 = .118

.118 - 0.02 = 0.098

In other words, porosity would have to be increased nearly an additional 10% of the total rock volume, or:

The pore water at the initially assumed 2% porosity would have to be replenished and boil nearly six times over.

At the SB-15-D site, which the above is meant to proxy, it seems like temperatures stayed pretty hot-- nearly isothermal at about 320C -- prior to the inferred onset of vapor-dominated conditions. This to me would seem to indicate that simple conductive cooling of the rocks from their thermal maximum here can't be invoked to help explain the large amount of heat loss required in going to the vapor-dominated state (in other words, the temperature probably hadn't conductively cooled to nearer the 243C final temperature before a vapor-dominated system began to develop). Another point -- The liquid- to vapor-dominated transition is believed to require very little recharge, so it seems a stretch to recharge and reboil waters in the hypothetical reservoir block six times over, as effective porosity in the block is surely nowhere near 12% (probably, in fact, <2%).

Another observation -- Pruess' 1985 VD model matrix permeability is given as 3 X 10^-18 m^2. This is your threshold for convection, so how can he call upon fluid migration within the block as a means to redistribute heat?

I know this is overly simplistic, but it was fun to think about it. Thanks for the tools.

Jeff

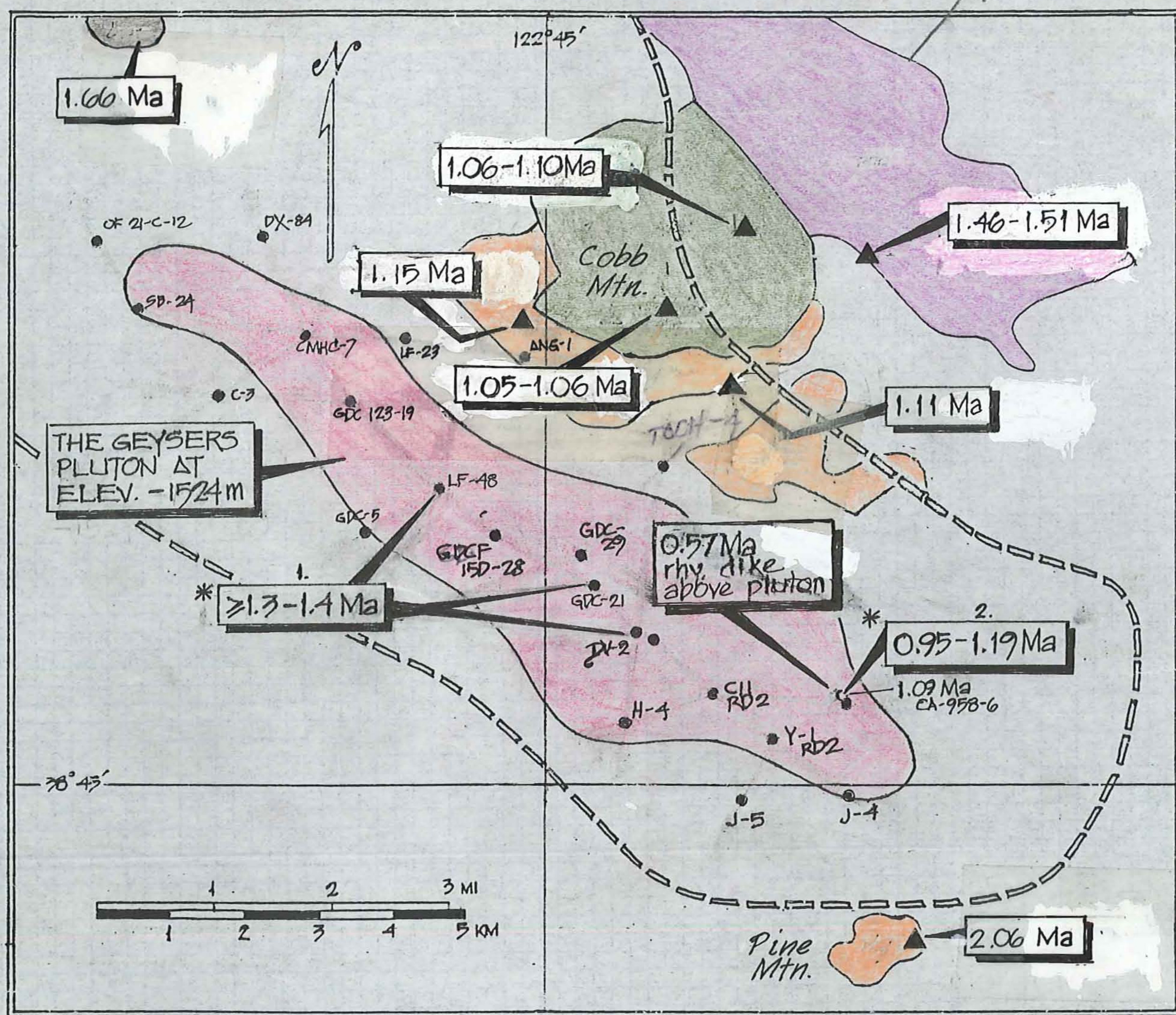
179.5

Lambert coordinates

31.8 = 6000

wrong loc.!

out line in color only



* $^{40}Ar/^{39}Ar$: otherwise K-Ar

1. Dalrymple, 1992   2. Pulka, 1991
otherwise Donnely-Nolan et al., 1981

GEOCHRONOLOGY OF IGNEOUS ROCKS IN THE GEYSERS AREA

Clear Lake Volcanics

Dacite

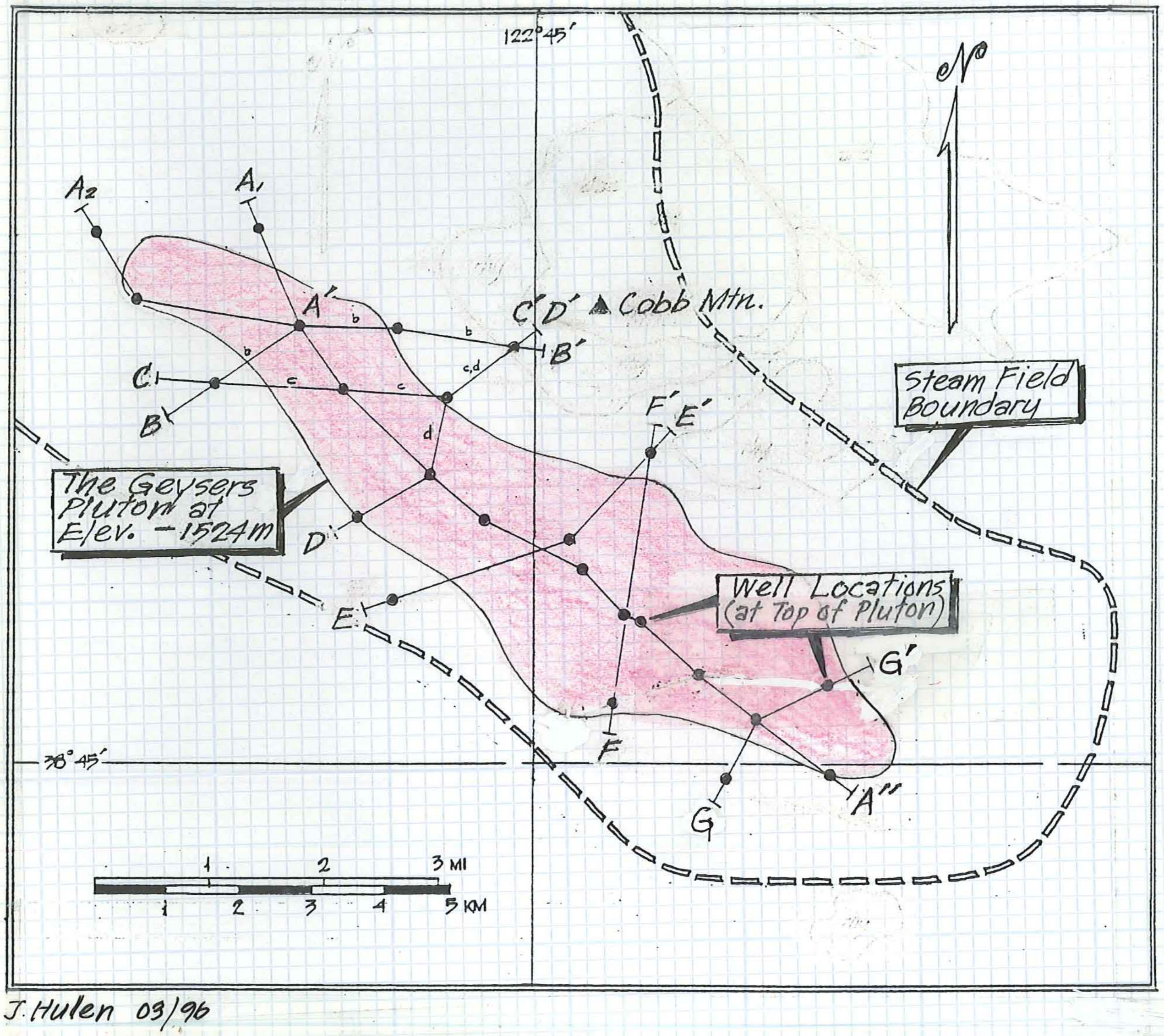
Rhyolite

Andesite

Basalt

The Geysers Pluton

Granite and Granodiorite



LOCATION MAP

Felsite

urchins restricted to microgranitoid and some of granite phases

URCHINS

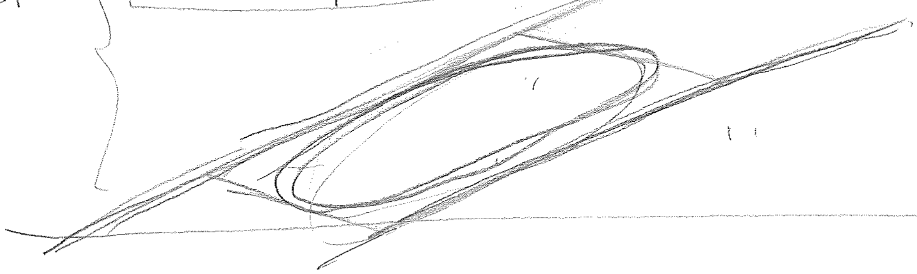
needle-like oxides probably grew rapidly along w/ qtz + fsp in undercooled carapice of silicic magma

What phase? Jeff will probe

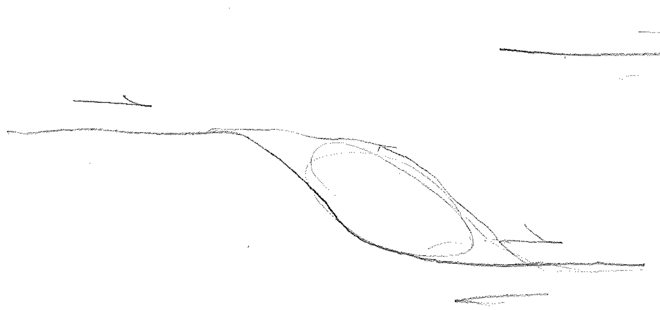
→ quench phases based on greatest abundance in microgranitoid

FSPS

Probe fsp in DV-2



iPS ~~Ø~~ CA 5636 WR-geochem



WP5.1 file cms.tex

Jeff,
Here are some notes I made on the thin sections I have, some of which are included (circled numbers).

Cobb Mountain Sequence

DCV- 1.08
DC - 1.06
RA - 1.11, 1.15

ANDESITE OF FORD FLAT (exposed on SE flank of Cobb Mtn.)

40: AFF- fn. gr. andesite of Ford Flat
5% cpx, 3% plag, <1% ol phenocrysts in groundmass of plag and glass (partially altered).

40-1 and 40-2: AFF- fn. gr. andesitic basalt? similar to BK unit at Konocti.

RHYOLITE OF ALDER CREEK

41: RA- rhyolite of Alder Creek collected on east side of Cobb Mt. near Whispering Pines\substitute for Fraser's chem sample F92-33.

41-1, 41-2, 41-3, 41-4

san, plag, qtz, bio, cpx, opx, hb, op; 1-5% qmi (quenched mafic inclusions) groundmass of hb, plag, op and glass. (multiple pyx + plag populations due to mixing)

CL61- RA- glassy rhyolite with san, plag, qtz, bio, pyx, and ilm? phenocrysts, not much evidence of mafic input in this sample.

42: RA?- rhyolite of Alder Creek — may be a separate rhyolite or rhyodacite lava not mapped as such
plag, san, qtz, bio, cpx, opx, cpx, op; 1-10% qmi groundmass of plag, opx?, and glass; phenocrysts of plag, opx, and cpx and xenocrysts of sodic plag and qtz.

42-3 contains qmi

DACITE OF COBB MOUNTAIN

83: DC- dacite of Cobb Mountain from near Unocal drill site near the summit of Cobb Mountain. Substituted for Fraser's chem sample F92-34.

83A: DC- host dacite
sodic plag, san, qtz, bio, hb, opx, cpx, op; 1-15% qmi groundmass of plag, opx, op, and glass, phenocrysts of cpx and opx, and xenocrysts of plag, qtz, and san (rapakivi).

The silicic endmember consists of sodic plag, sanidine, bio, quartz, Fe-rich opx and cpx, and ilm? Hornblende occurs as groundmass grains. The mafic endmember consists of calcic plag, and Mg-rich opx and cpx.

83B1: DC- quenched inclusion and adjacent dacite host.
Dacite host has resorbed but unmantled qtz, sodic plag with very thin fritted margins, and bio partially rimmed by opaques.
Quenched inclusion contains 3 sodic plag with fine-fritted rims and 1 quartz with incipient augite corona.

could find these

83B2: DC- quenched inclusion and adjacent dacite host.
Dacite host has resorbed but unmantled qtz, sodic plag with very thin fritted margins, and bio partially rimmed by opaques.
Quenched inclusion contains two sanidine grains, one with fine-fritted rim (plag overgrowth?), the other (bigger) with a partial coarse-grained mantle of plag and fine-fritted texture on both the sanidine and the plag mantle. A sodic plag grain has a thick fine-fritted margin.

83C: DC- dacite host with two small quenched inclusions that are relatively cr. gr. and lack silicic endmember crystals

83D: DC- interlayered dacite host and quenched inclusion-like bands

----

84: DC- dacite of Cobb Mountain
san, plag, qtz, bio, cpx, opx, op; 1-15% qmi groundmass of plag, opx, op, and glass, phenocrysts of cpx and opx, and xenocrysts of plag, qtz, and Fe-rich pyx-bio clots.
84-1 84-3 → host + large qmi
CL223: DC- typical Cobb dacite with plag, san (fn.gr. rapakivi), quartz, bio, and pyroxene.

DACITE OF COBB VALLEY 70-1

distinct from other units

70: DCV- Dacite of Cobb Valley
plag, opx, cpx, op, with minor qtz and san

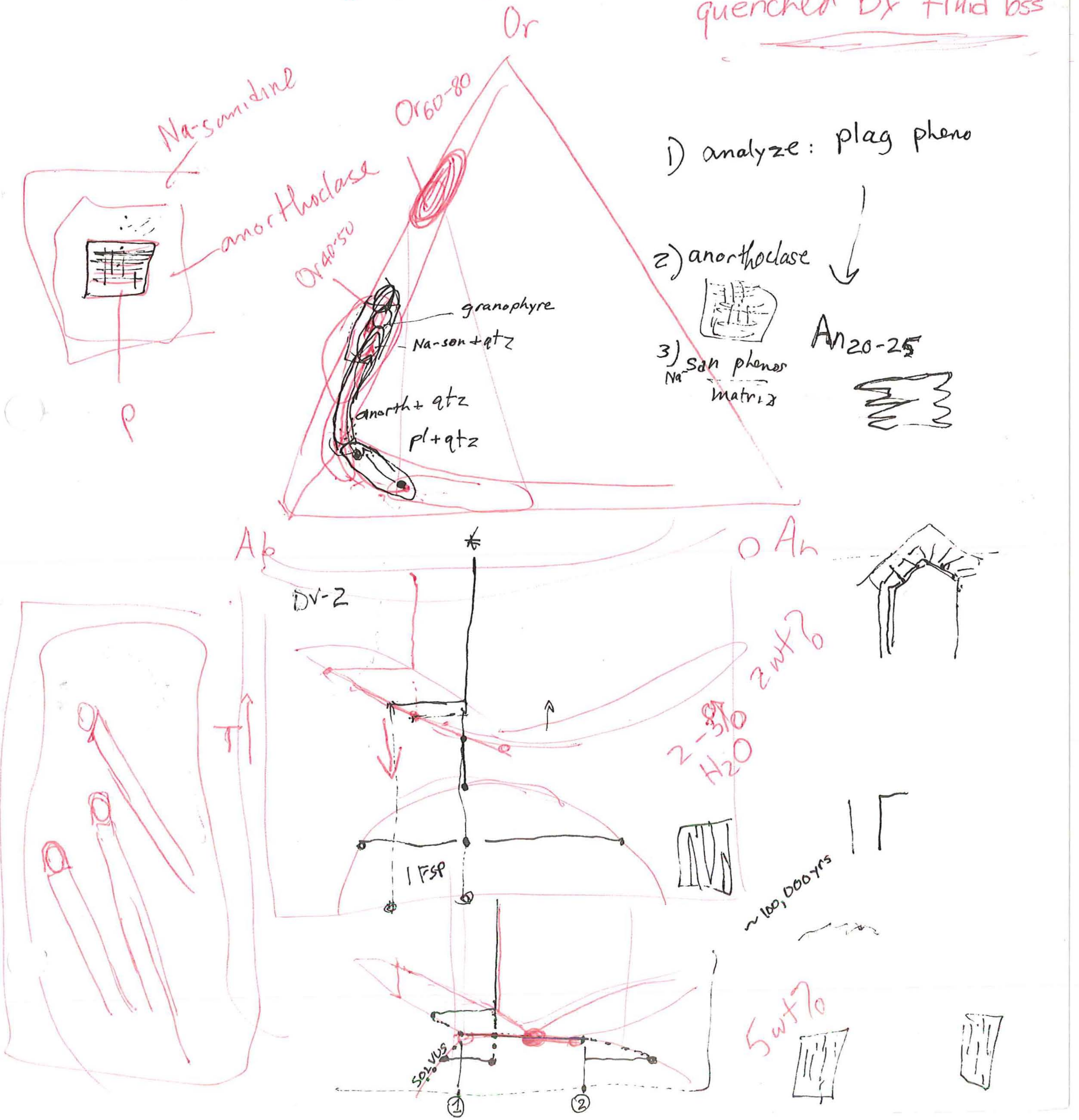
H75-9B: DCV- Very clean sample of pyroxene dacite
plag, opx, cpx, op- much more mafic than DC.
----
samples

AFF: SCL40
RA: CL61, SCL39, SCL41, SCL42?, SCL167
DC: CL223, SCL83, SCL84, SCL44?, SCL168
DCV: H75-9b, SCL70, F91-17

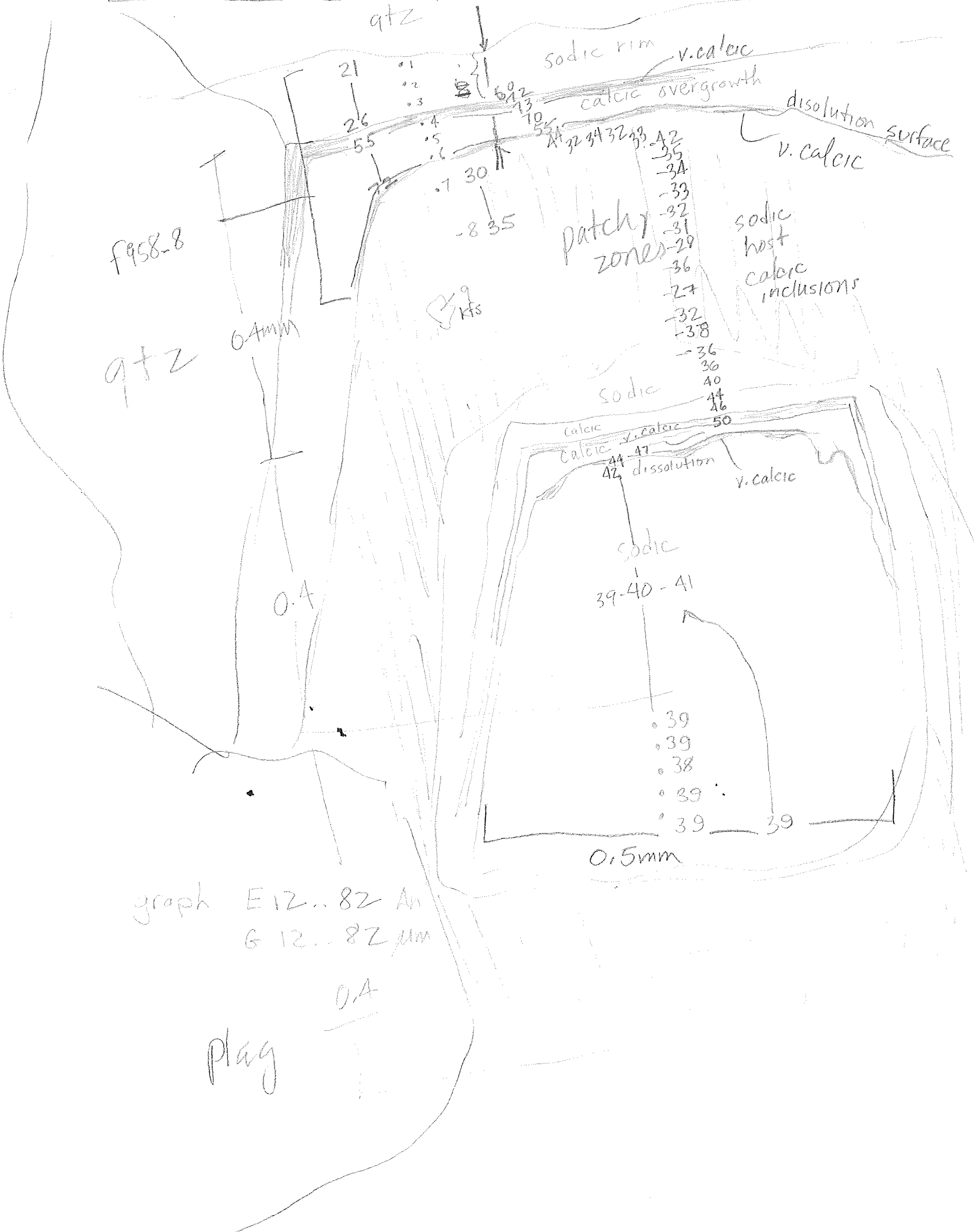
DCV F91-17
DCV- plag - opx - minor ~~cpx~~ opaques
cpx qtz
qmi

DV-2

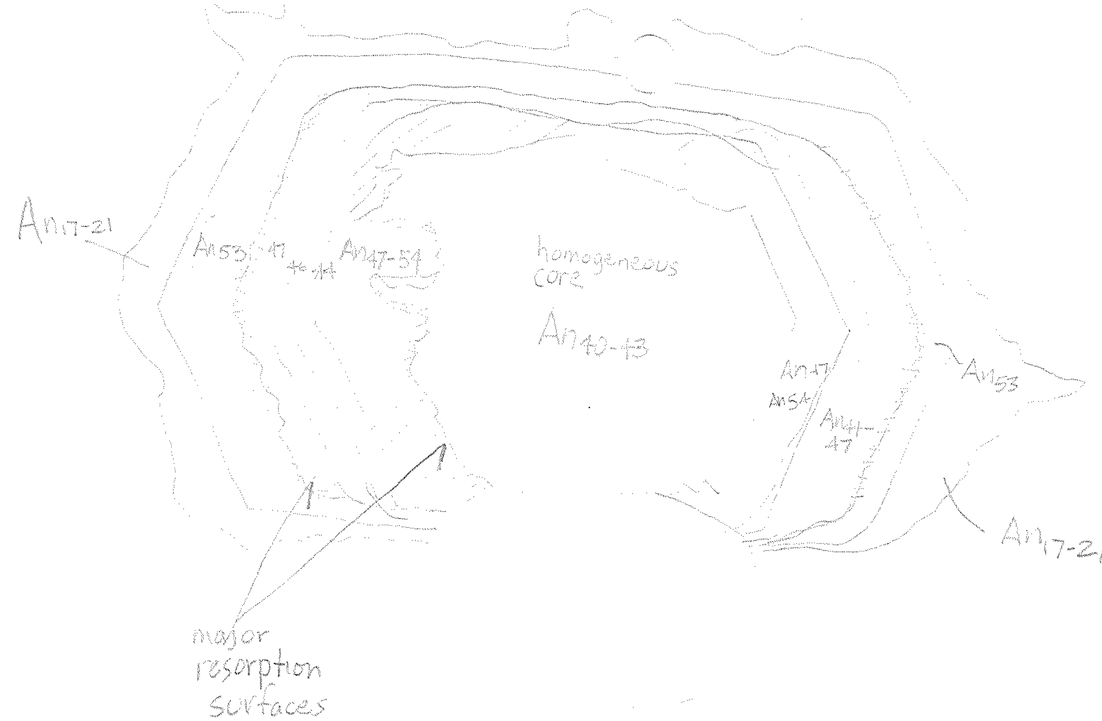
"hypersolvus" granite
graphic granite like Alld
quenched by fluid loss



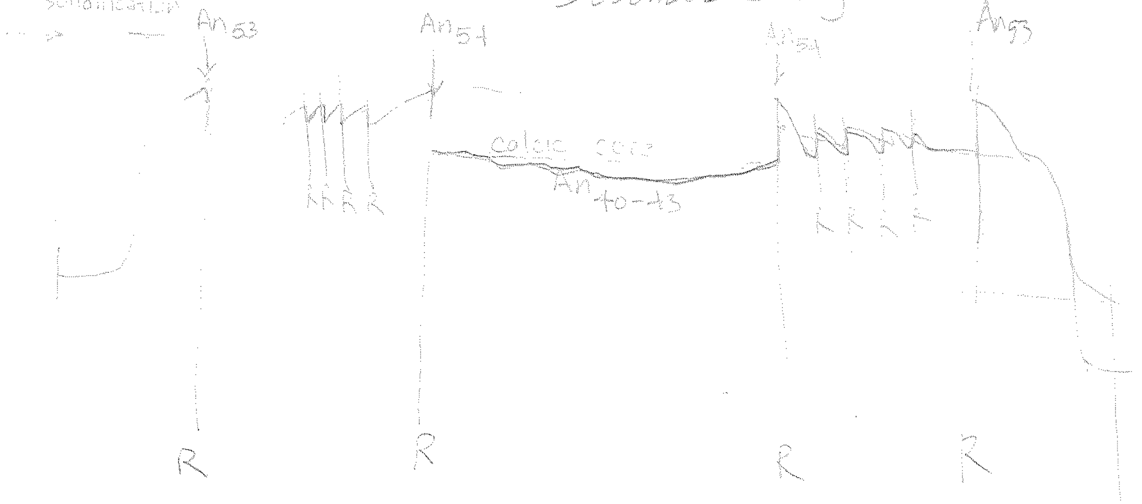
CA958-2 Pheno 8



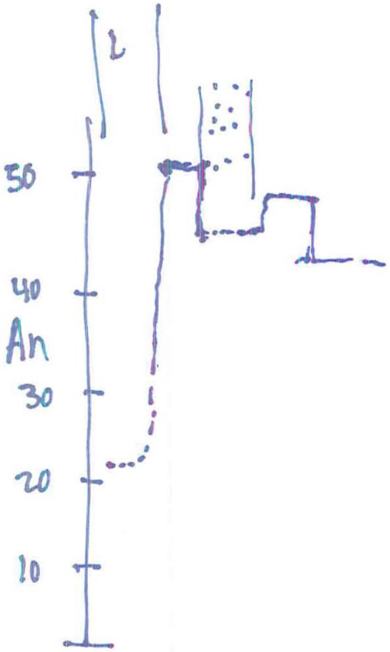
1A

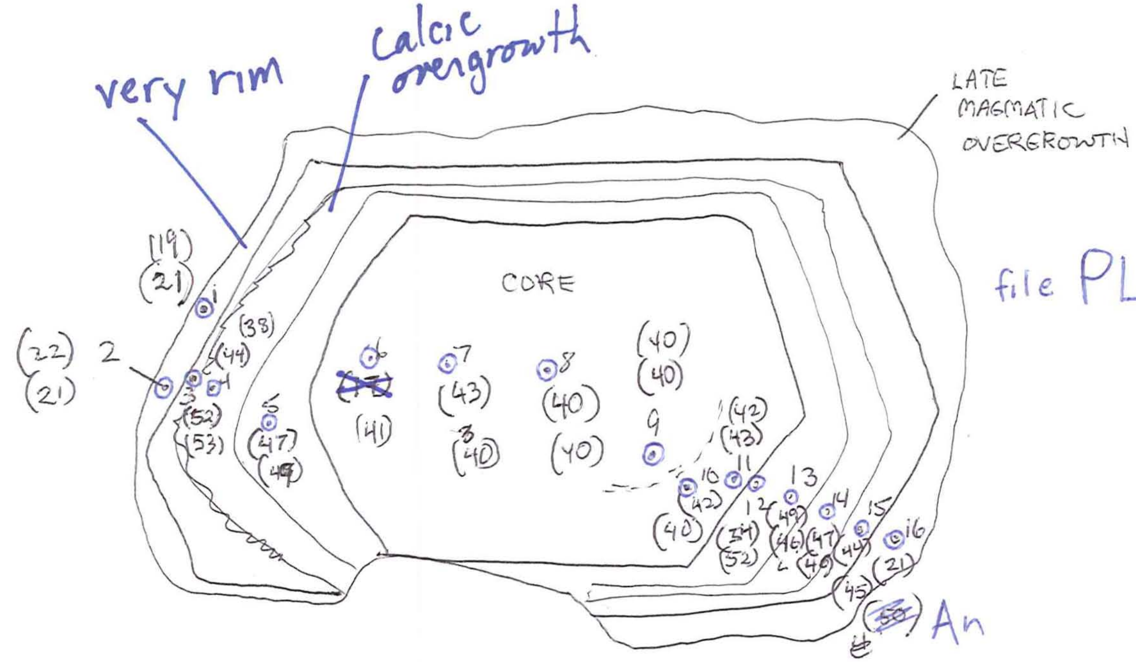


Idealized Zoning Profile

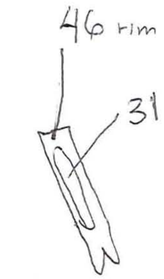


958-6 (2) 1a

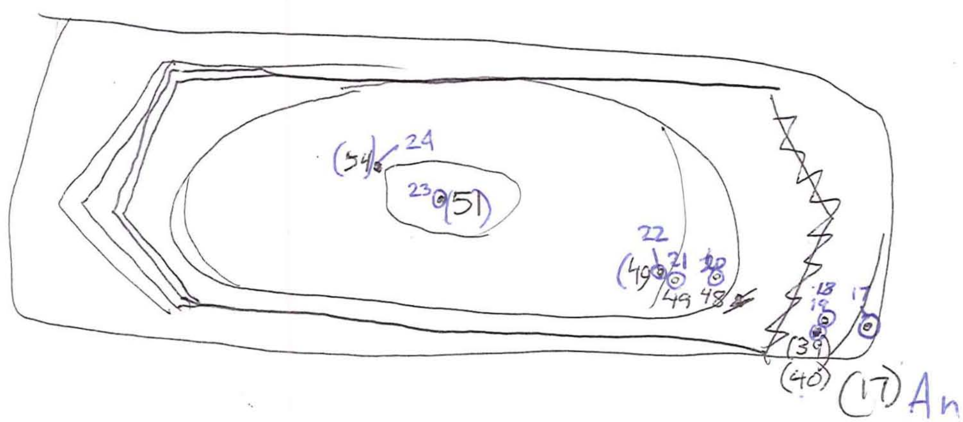




file PL1 = traverse of 16 pts
pt6 deleted



1b



Unocal Corporation
Geothermal & Power Operations
1300 North Dutton Avenue
Santa Rosa, California 95401
Telephone (707) 521-7600
Facsimile (707) 521-7604

UNOCAL 76

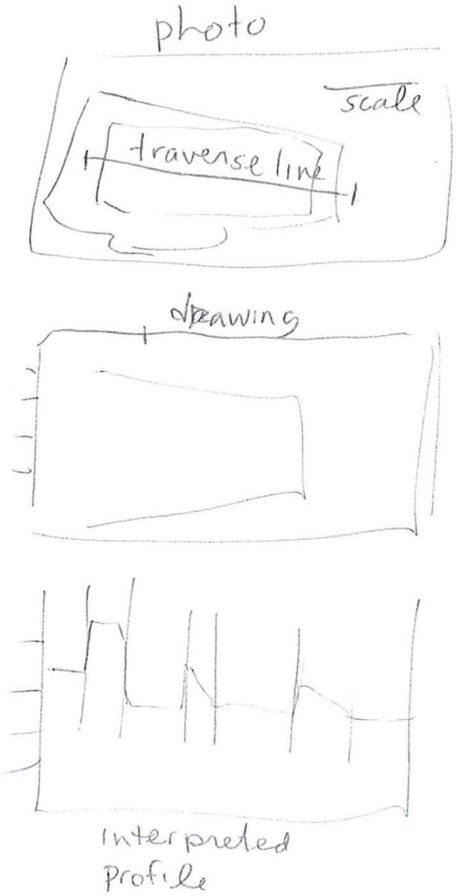
2/11

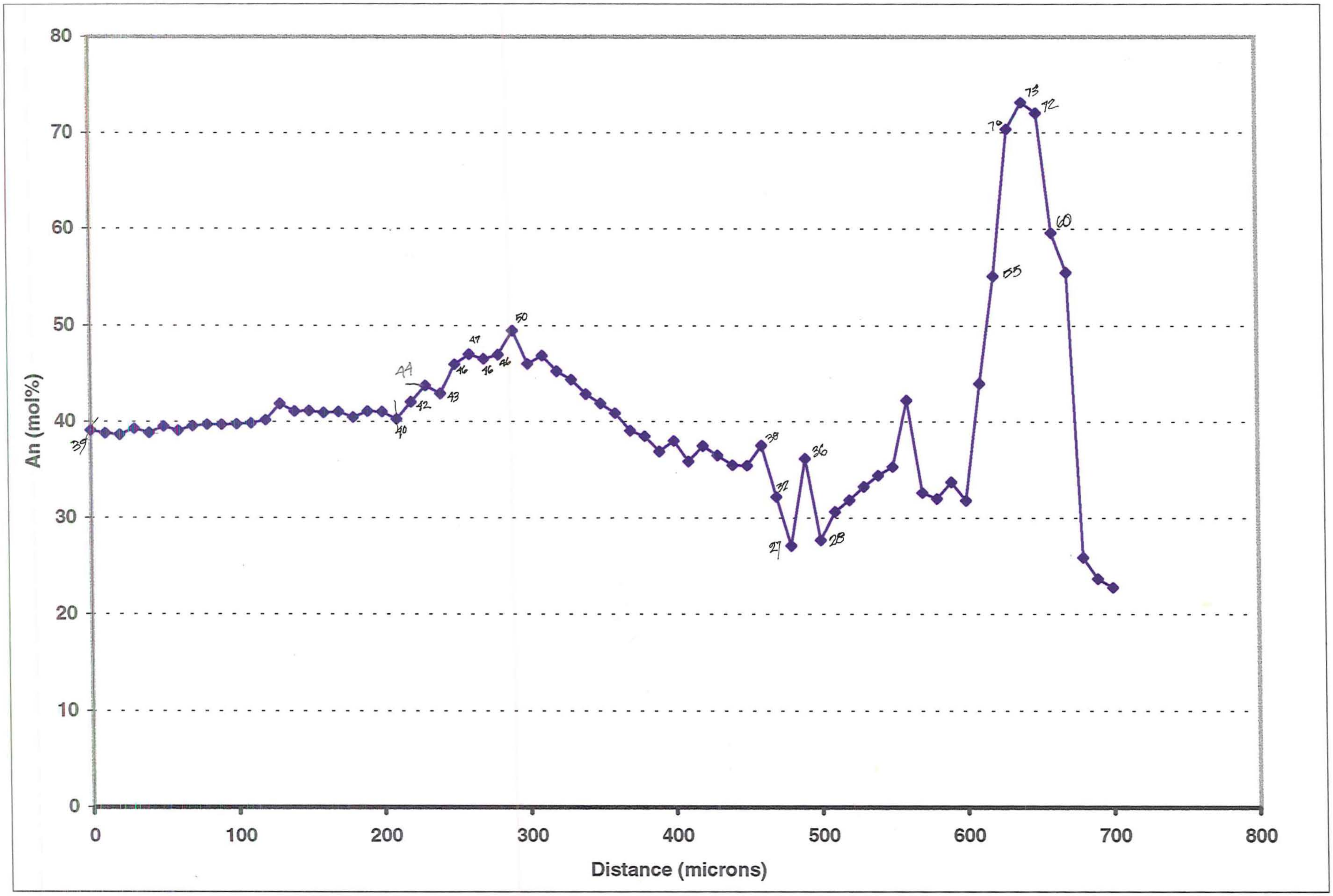
Jeff,

Here are some photos and drawings of zoned plag with EMP analyses. It will give you an idea what I was thinking as far as figures go.

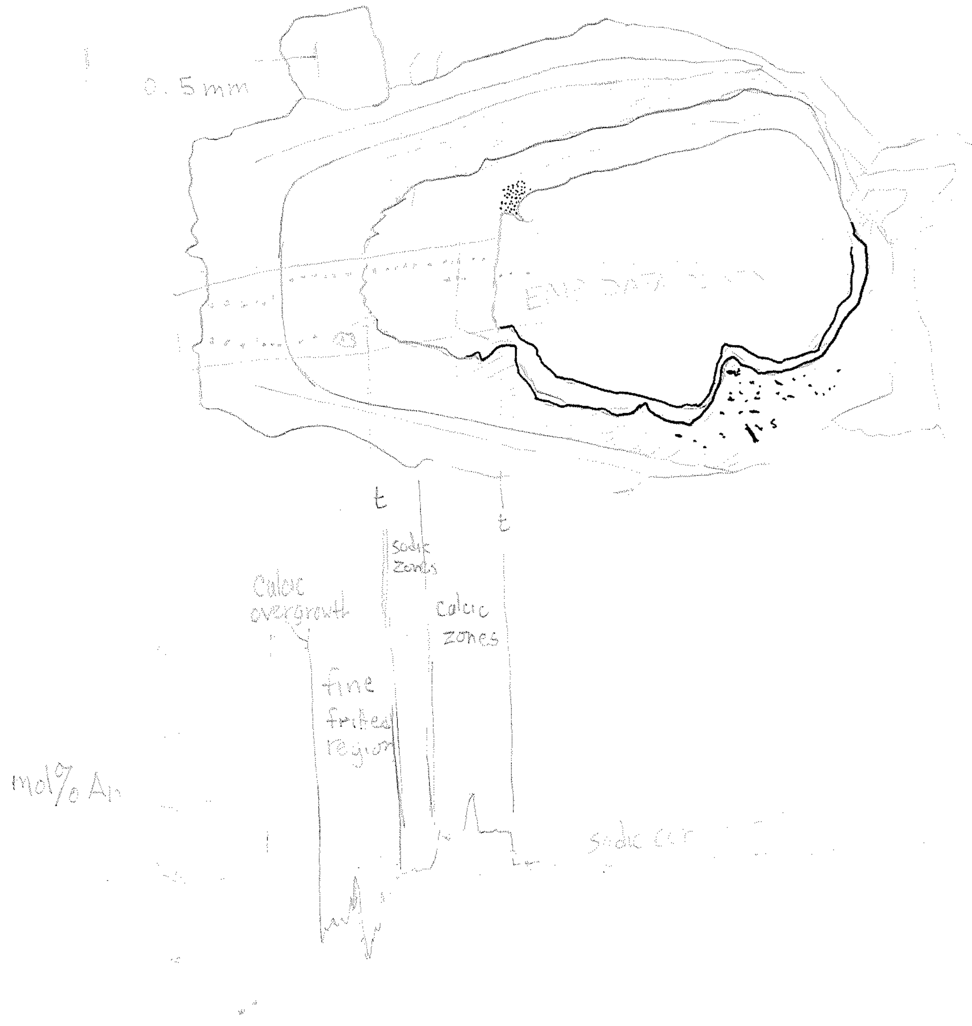
Better run.

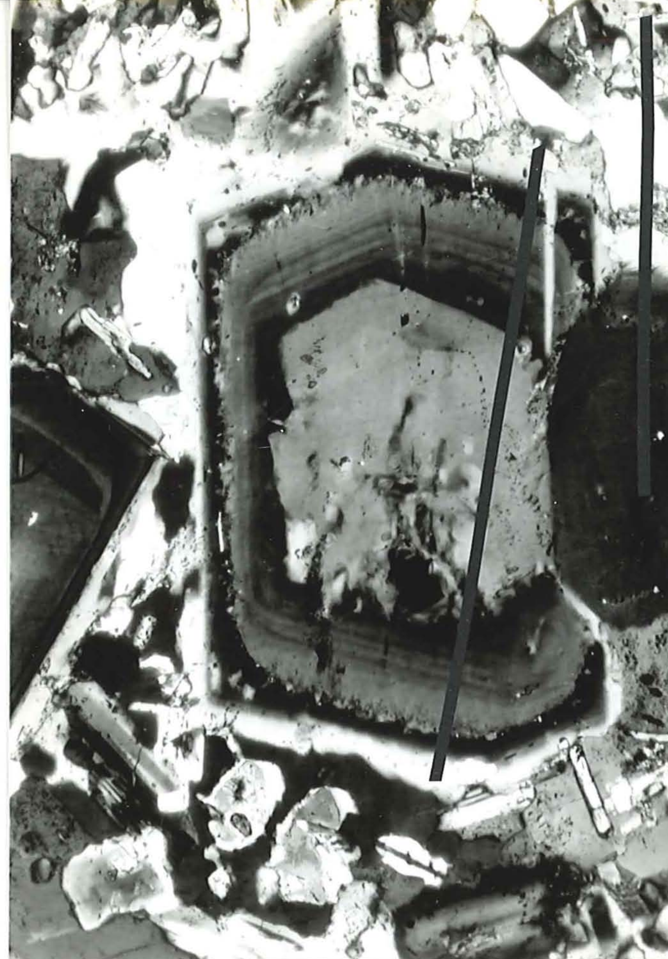
Jim

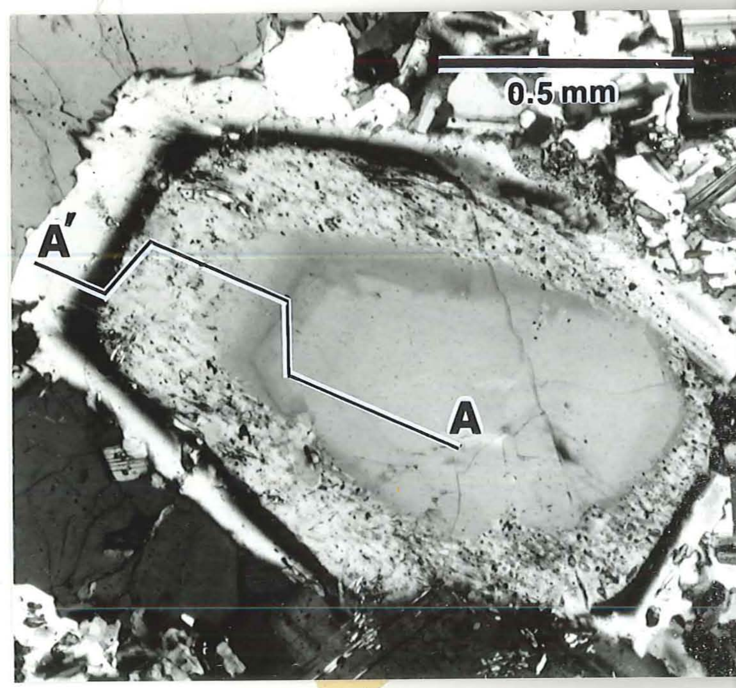



An (mol%)
Distance (microns)
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
700
800
39
40
42
43
44
46
46
47
46
50
38
32
27
36
28
70
73
72
60
55

62.5=100


0.5 mm
t
t
sodic zones
calcic overgrowth
calcic zones
fine fritted region
mol% An




0.5 mm
A′
A

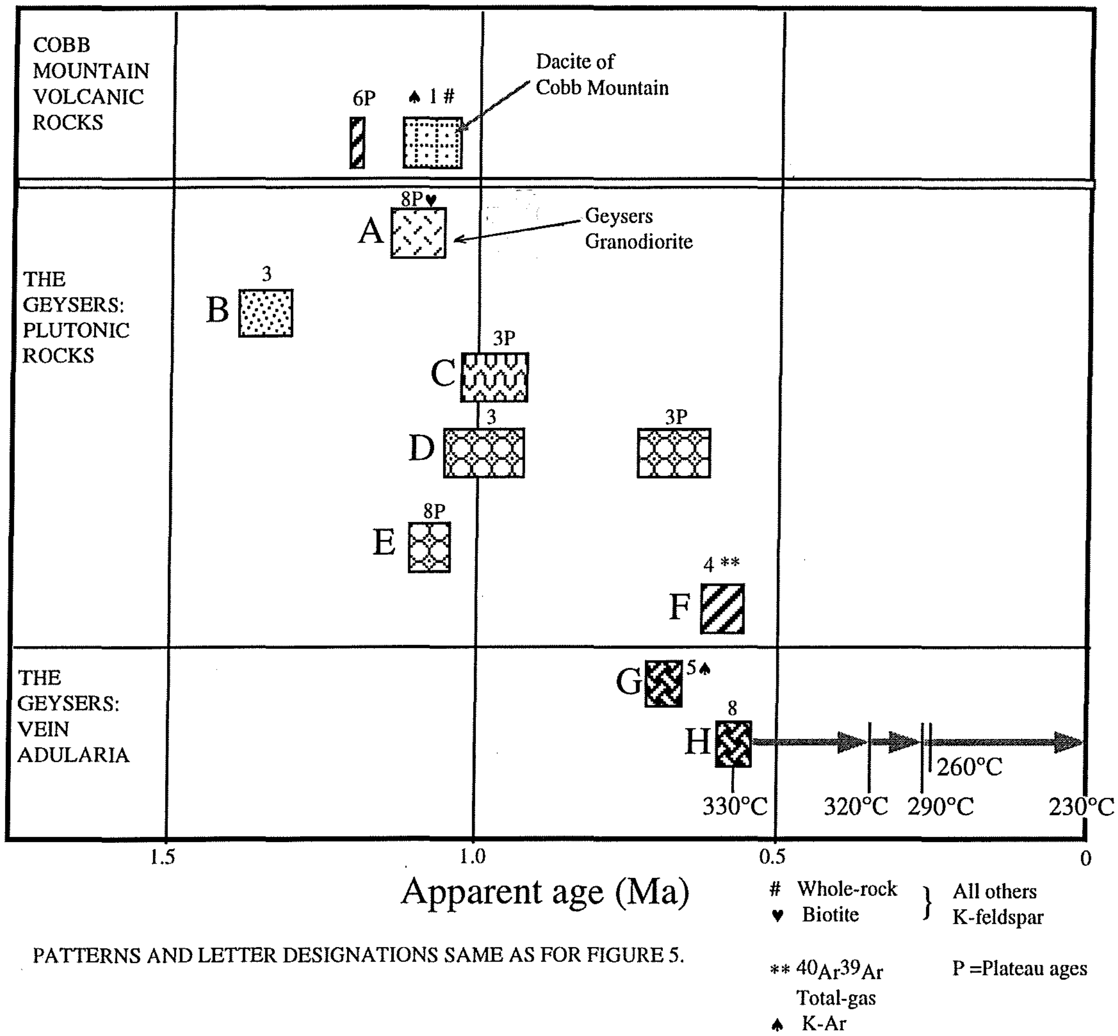


Figure 6. $^{40}Ar/^{39}Ar$ minimum ages for The Geysers plutonic and volcanic rocks and vein adularia. Note remarkable match for dacite of Cobb Mountain (whole-rock K-Ar) and Geysers granodiorite (biotite $^{40}Ar/^{39}Ar$ incremental-heating plateau). Arrows in lower right corner depict thermal history of adularia according to model 2 (Fig. 7). Ages include estimate errors.

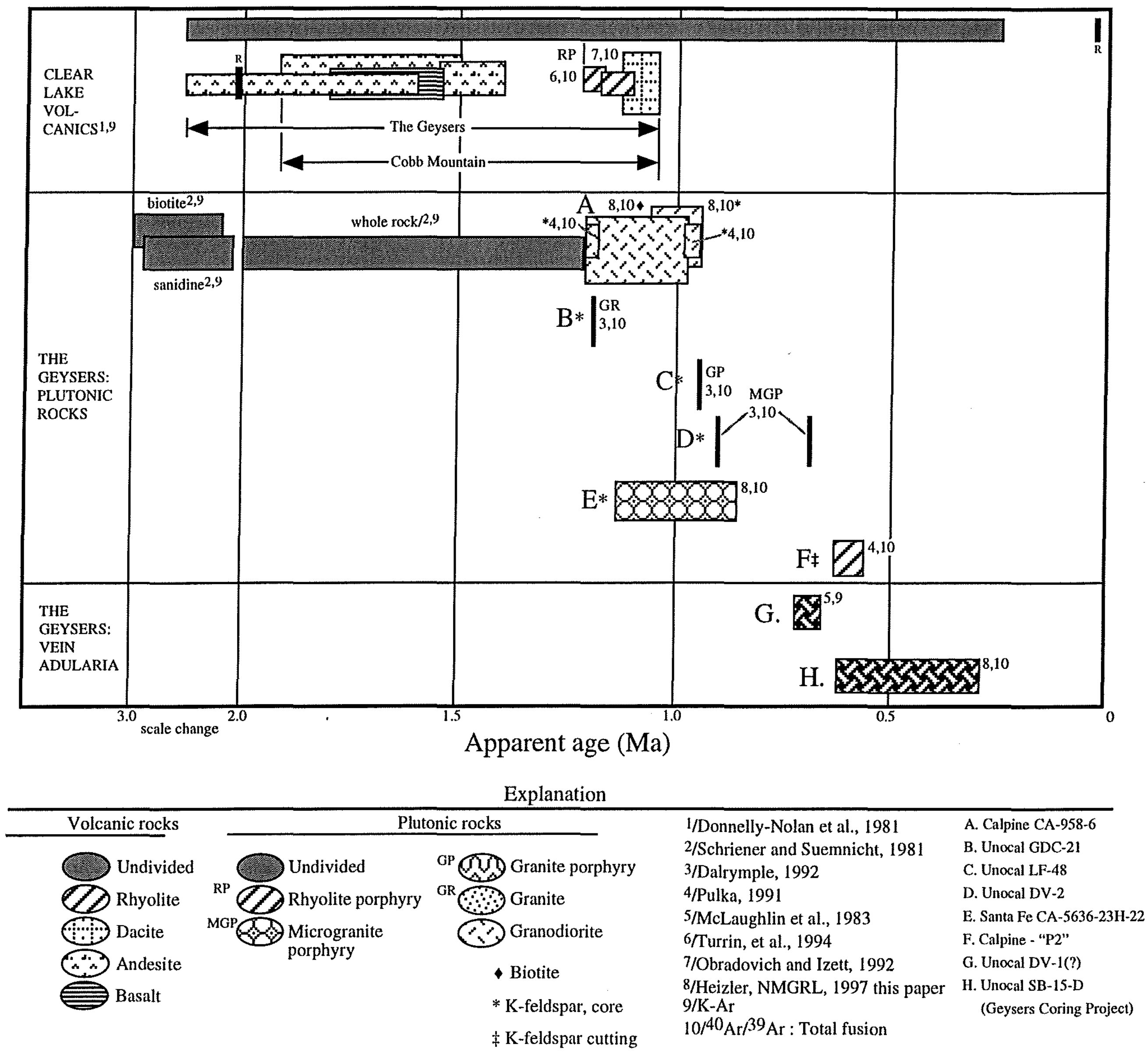
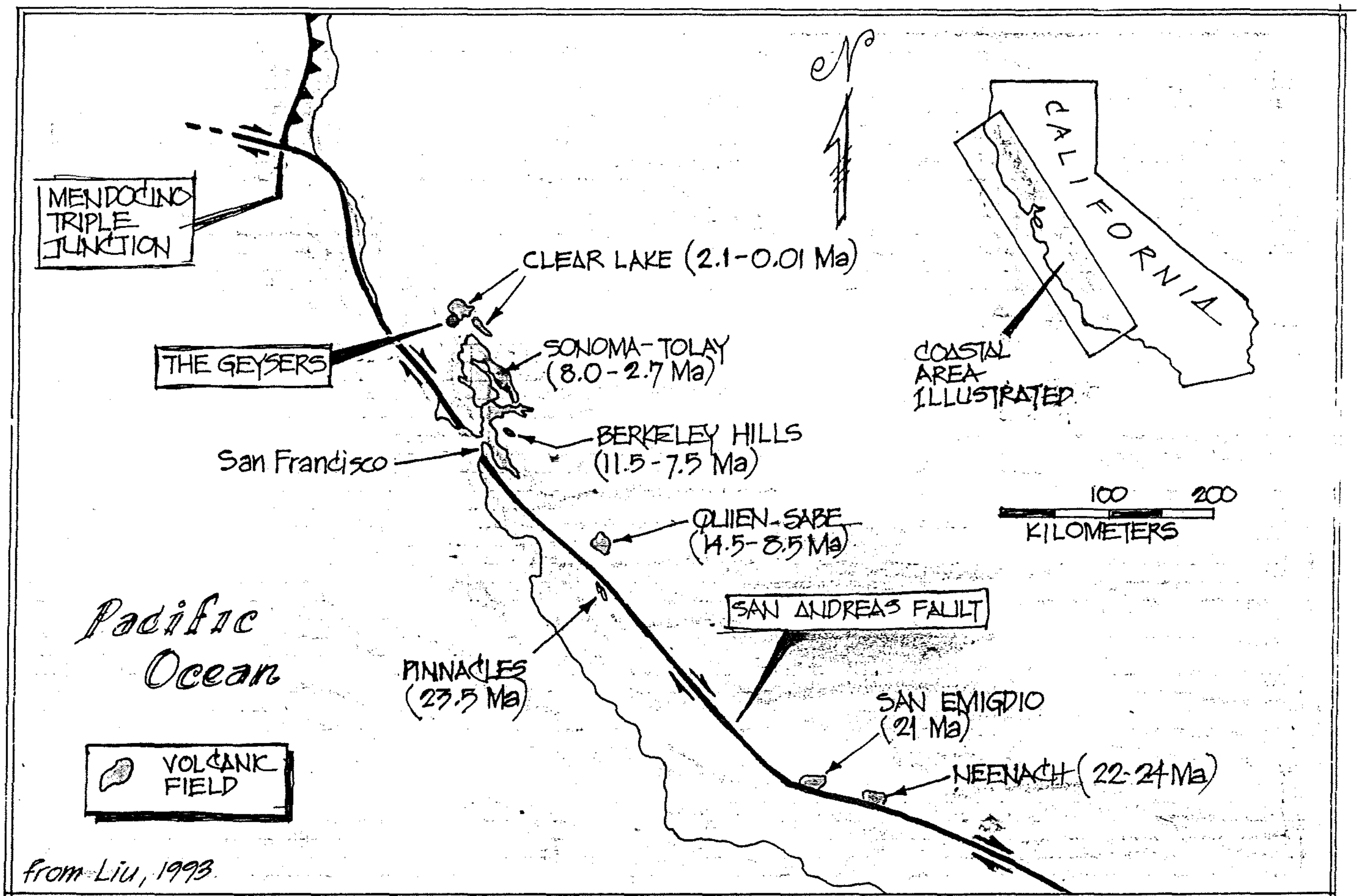


Figure 5. Summary of published and new K-Ar and 40Ar/39Ar total gas age dates for igneous rocks and vein adularia from The Geysers and the Clear Lake volcanic field. Ages include estimated errors.


N
CALIFORNIA
COASTAL AREA ILLUSTRATED
MENDOCINO TRIPLE JUNCTION
CLEAR LAKE (2.1-0.01 Ma)
THE GEYSERS
SONOMA-TOLAY (8.0-2.7 Ma)
BERKELEY HILLS (11.5-7.5 Ma)
San Francisco
100 200
KILOMETERS
QUIEN-SABE (14.5-8.5 Ma)
Pacific Ocean
SAN ANDREAS FAULT
PINNACLES (23.5 Ma)
SAN EMIGDIO (21 Ma)
NEENACH (22-24 Ma)
VOLCANIC FIELD
from Liu, 1993

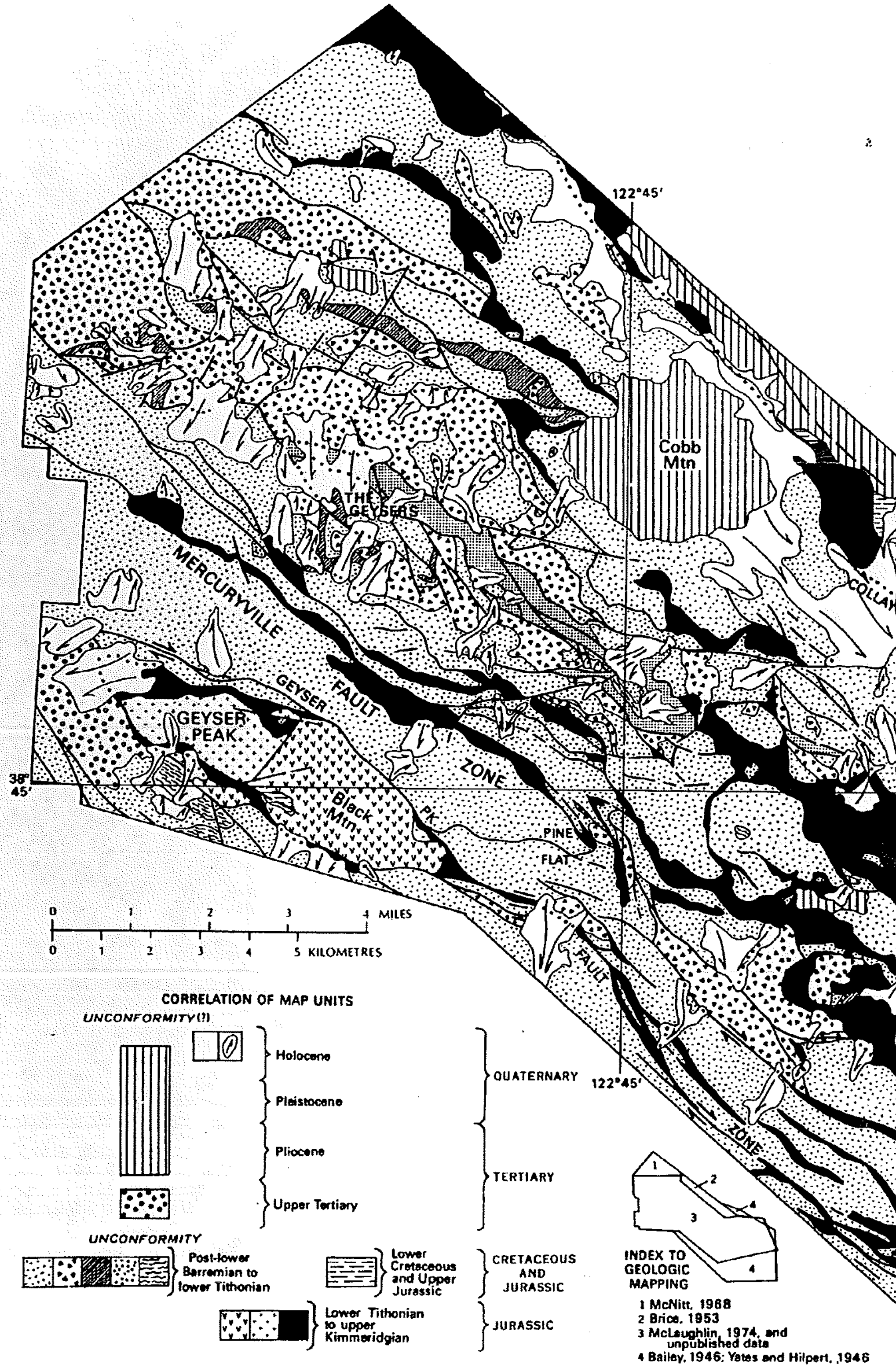


Figure 2. Generalized geologic map of the Geysers area, emphasizing the pre-Tertiary rocks.

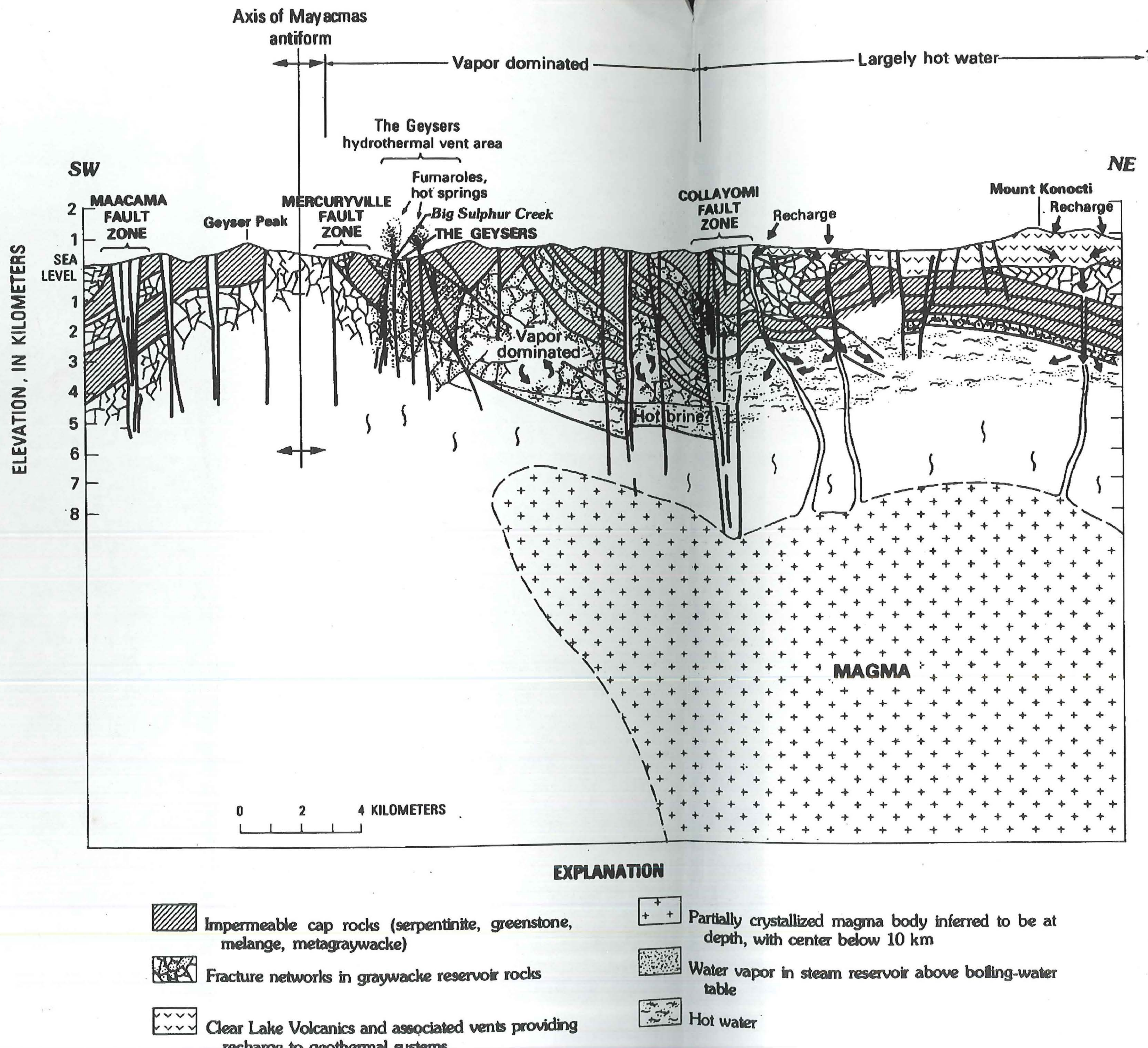
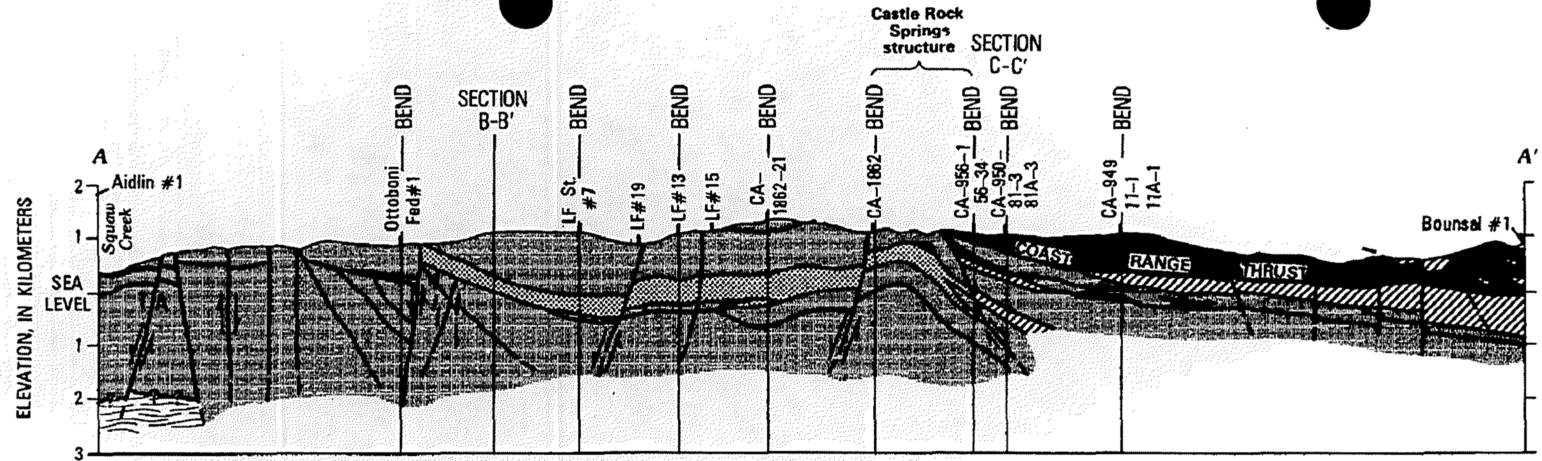
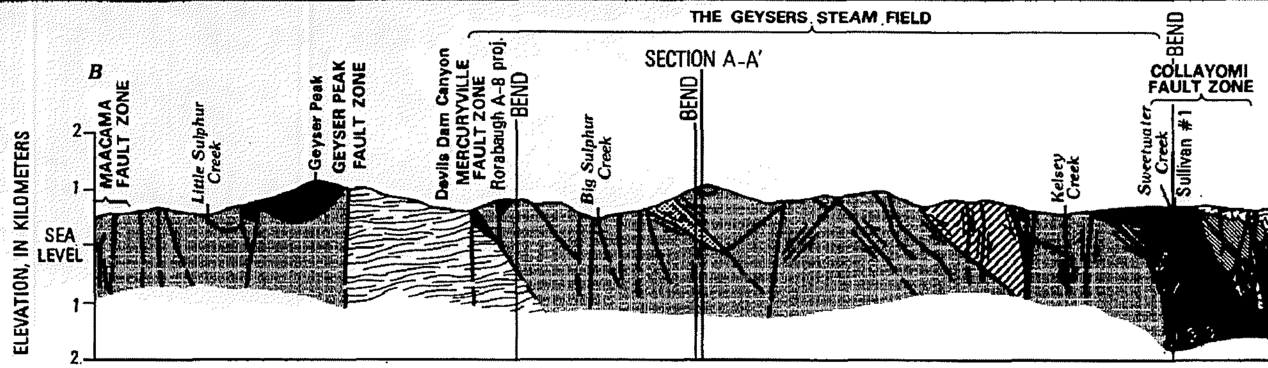
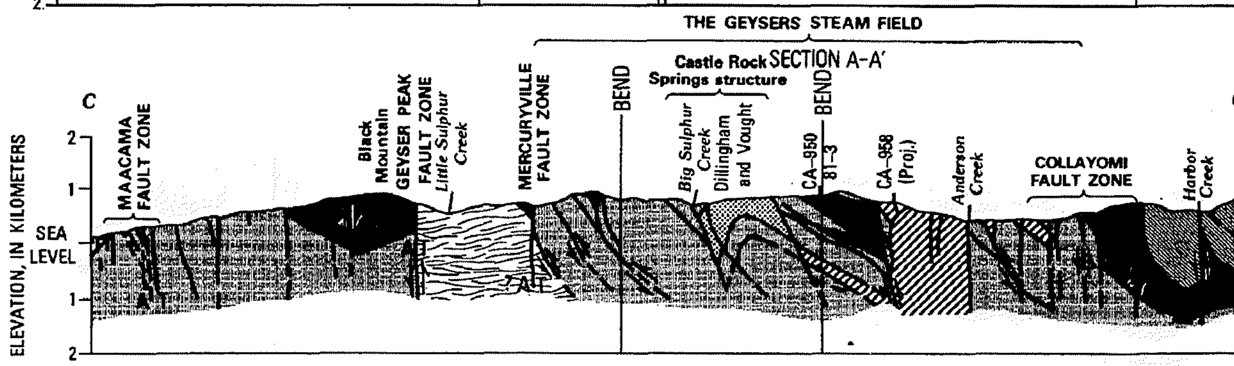


FIGURE 6.—Structural model of the Geysers geothermal system. Modified after McLaughlin (1977b).







EXPLANATION

Clear Lake Volcanics (late Tertiary and Quaternary)

Sonoma Volcanics and associated alluvial deposits (Pliocene)

Fluvial and lacustrine deposits (late Tertiary)

Great Valley sequence (Late Jurassic and Cretaceous)

Ophiolite (Late Jurassic)—*Composed of serpentinite, gabbro, diabase, basalt flows, mafic breccia, and minor chert*

Franciscan assemblage (Late Jurassic and Cretaceous)

Structural unit 3—*Lawsonitic metasandstone with minor metachert and metagreenstone* } Eastern belt

Structural unit 2—*Melange and broken formation of sandstone, shale, greenstone, chert, blueschist amphibolite, eclogite, and minor lawsonitic metasandstone* } Central belt

Structural unit 1—*Sandstone and shale*

Actinolitic serpentinite

Contact

Fault—*Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side; arrow shows relative horizontal movement. In cross section, T indicates movement toward observer, A movement away from observer*

Thrust fault—*Sawteeth on upper plate; dashed where approximately located.*

A-1862₁ Surface location and names of geothermal well along line of cross section

ENLARGE 1.174X

(SEE OTHER SIDE)

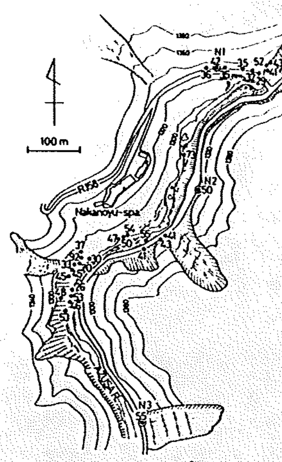
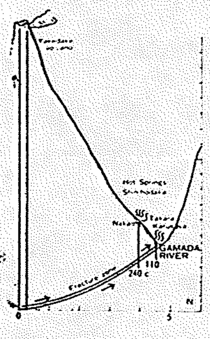


Fig. 9



g. 10

FRACTURING IN THE NORTHWEST GEYSERS, SONOMA COUNTY, CALIFORNIA

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Mark A. Walters (2)
Jeffrey B. Hulen (1)

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(2) Coldwater Creek Operator Corporation, 1400 N. Dutton Ave., Ste 23, Santa Rosa, CA 95401

ABSTRACT

Fracturing in the northwest Geysers is discussed in terms of both geologic mapping and measurements of fracture trends in oriented core. Faults of importance to the geothermal system include thrust faults followed in time by northeast trending faults with apparent right lateral offset and then northwest trending faults with apparent normal displacement. Measurements of fracture orientations in core show trends perpendicular to the least principal stress as well as fracturing apparently controlled by lithologic variables. Fracturing in The Geysers is complex, and different areas of the steam field may be dominated by fractures of different origins, and orientations.

INTRODUCTION

The nature, distribution, and orientation of fractures in The Geysers vapor-dominated geothermal field are of obvious importance in exploration and development drilling, reservoir modeling, and planning fluid injection strategies for enhanced steam production. McLaughlin (1981) and Nielson and Brown (1990) briefly summarized previous fracture studies at The Geysers in the context of prior and and modern stress regimes.

The Geysers is located in a region of active strike-slip faulting often associated with the San Andreas fault zone. Within this region, the greatest horizontal principal stress is oriented about N10E, and the least horizontal principal stress about N80W. The corresponding intermediate principal stress is approximately equal in magnitude to the greatest horizontal principal stress and has a vertical orientation (Oppenheimer, 1986). Oppenheimer further demonstrated that this stress system has been responsible for historical seismic activity in The Geysers geothermal system.

Beall and Box (1989), McNitt et al. (1989), and Thompson and Gunderson (1989) concur that major steam-producing fractures in metagraywacke host rocks at The Geysers are of random orientation with many being subhorizontal to horizontal. Nielson and Brown (1990) proposed that the flat fractures formed by collapse when underlying felsic magma withdrew. These same authors also invoked a structural-arch model to account for the fact that shallow-dipping fractures remained open in spite of the weight of the overlying rock column.

Within the local structural framework of the Northwest Geysers steam field (Fig. 1), this paper discusses the nature and orientation of fractures and their mineralized analogues (veinlets) in drill cores from three

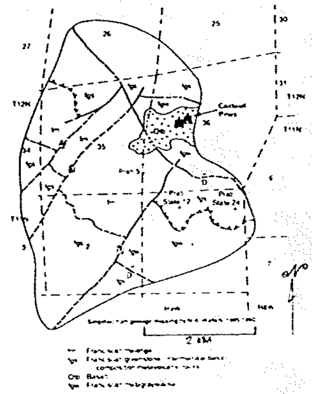


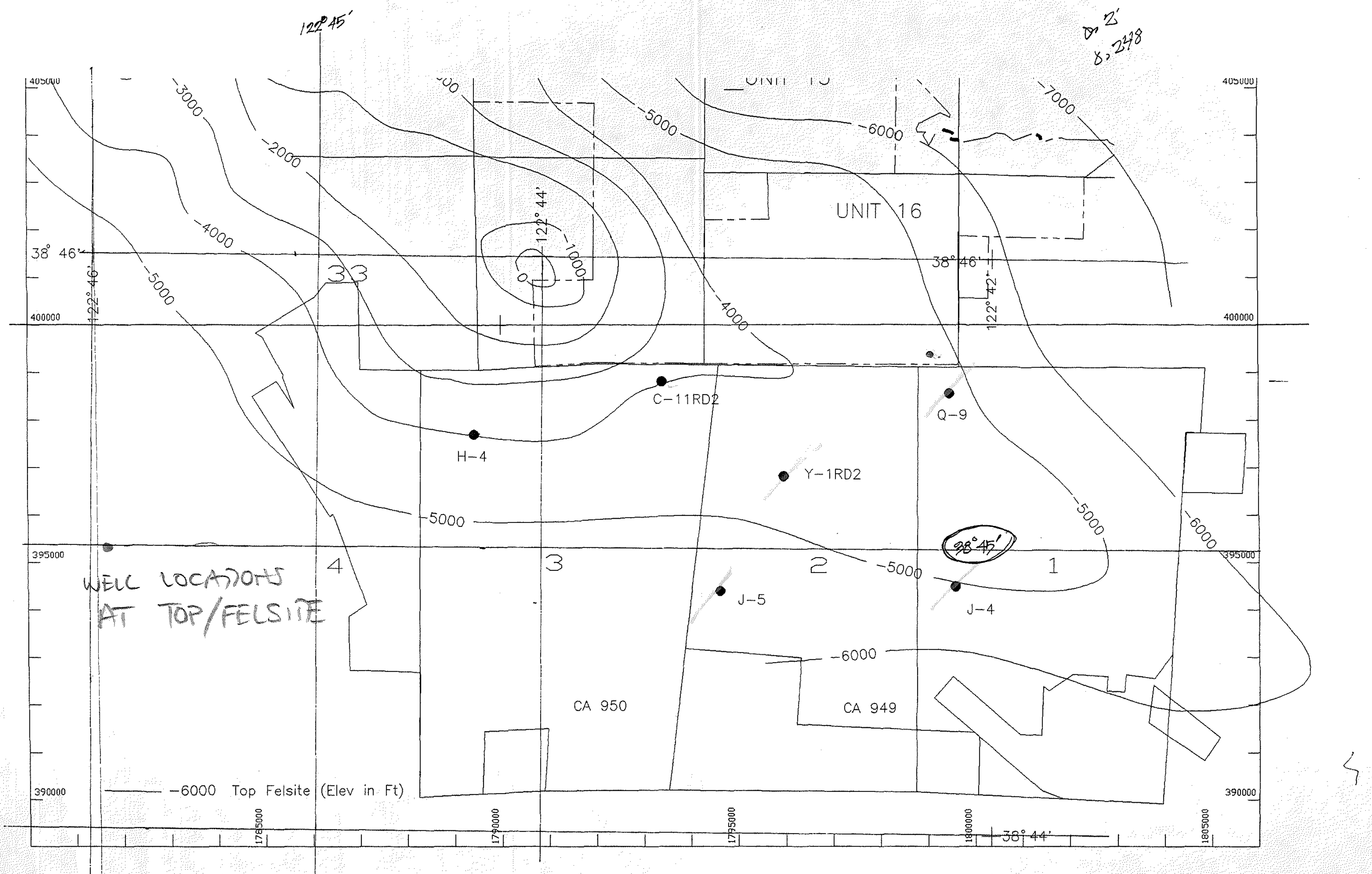
Figure 1. Generalized geologic map of the Northwest Geysers

geothermal wells. Two of these cores, from the field's relatively impermeable caprock in wells Prati 5 and Prati State 24 (Fig. 1), are oriented. The third, but unoriented core was retrieved from the upper portion of the productive steam reservoir in well Prati State 12. Detailed descriptions of the Prati 5 and Prati State 12 cores can be found in a companion paper (Hulen et al., this volume).

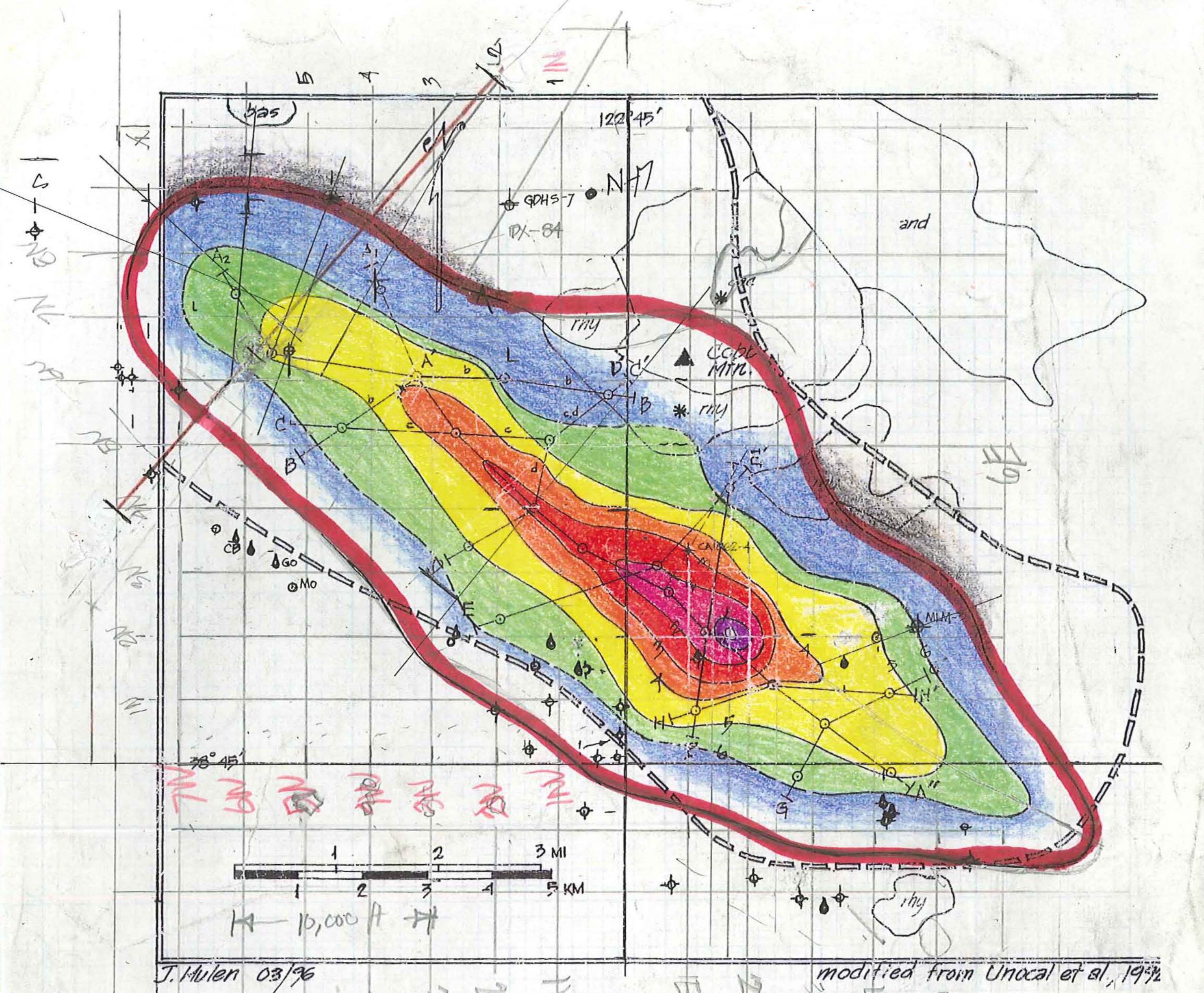
GEOLOGIC MAPPING

Figure 1 is a simplified geologic map of the Northwest Geysers area, abstracted from detailed mapping completed by one of us (Walters) between 1985 and 1990; each of the faults and contacts shown on the map was carefully field-traced. The map's interpretive aspects, such as fault offsets, are based on field relationships combined with subsurface data from geothermal wells.

Faults of several ages and styles are exposed in the Northwest Geysers. The oldest are local shears within



SOUTH EAST GEYSERS STEAMFIELD



ELEVATION, TOP OF THE GEYSERS PLUTON

- +305m [+1000 ft] to MEAN SEA LEVEL
- MEAN SEA LEVEL TO -305m [-1000 ft]
- -305m to -610m [-1000 to -2000 ft]
- -610m to -914m [-2000 to -3000 ft]
- -914m to -1219m [-3000 to -4000 ft]
- -1219m to -1524m [-4000 to -5000 ft]
- -1524m to -1829m [-5000 to -6000 ft]
- -1829m to -2134m [-6000 to -7000 ft]
- < -2134m [-7000 ft]

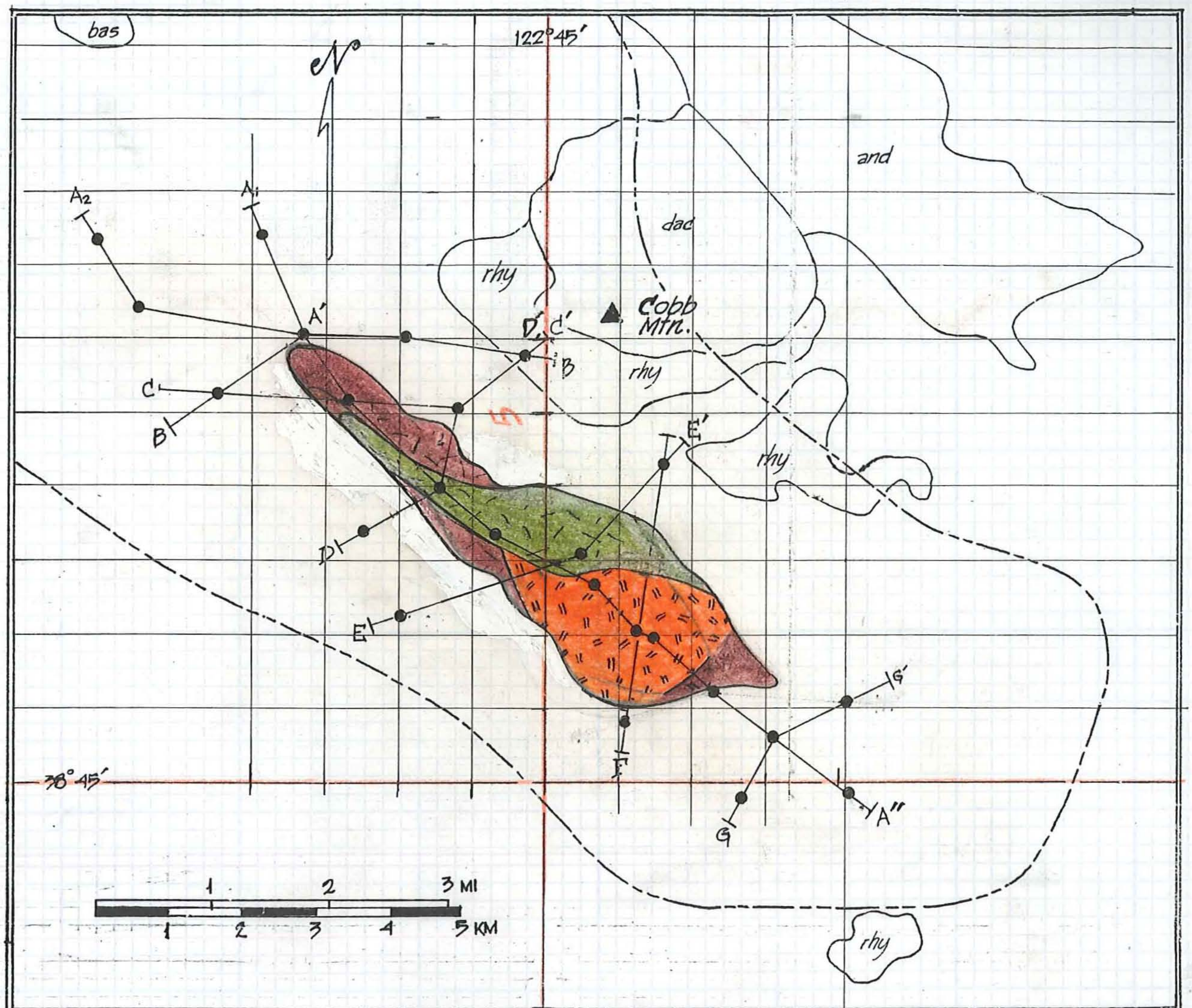
DRAFT

GEOLOGIC MAP OF THE GEYSERS PLUTON
AT ELEVATION (-) 1829 m [-6000 ft]

PYROXENE-HORNBLENDE-BIOTITE GRANODIORITE

PYROXENE BIOTITE GRANITE

DRAFT



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GEOLOGIC MAP OF THE GEYSERS PLUTON
AT ELEVATION (-)1219 m [-4000 ft]

PYROXENE-HORNBLENDE-BIOTITE GRANODIORITE

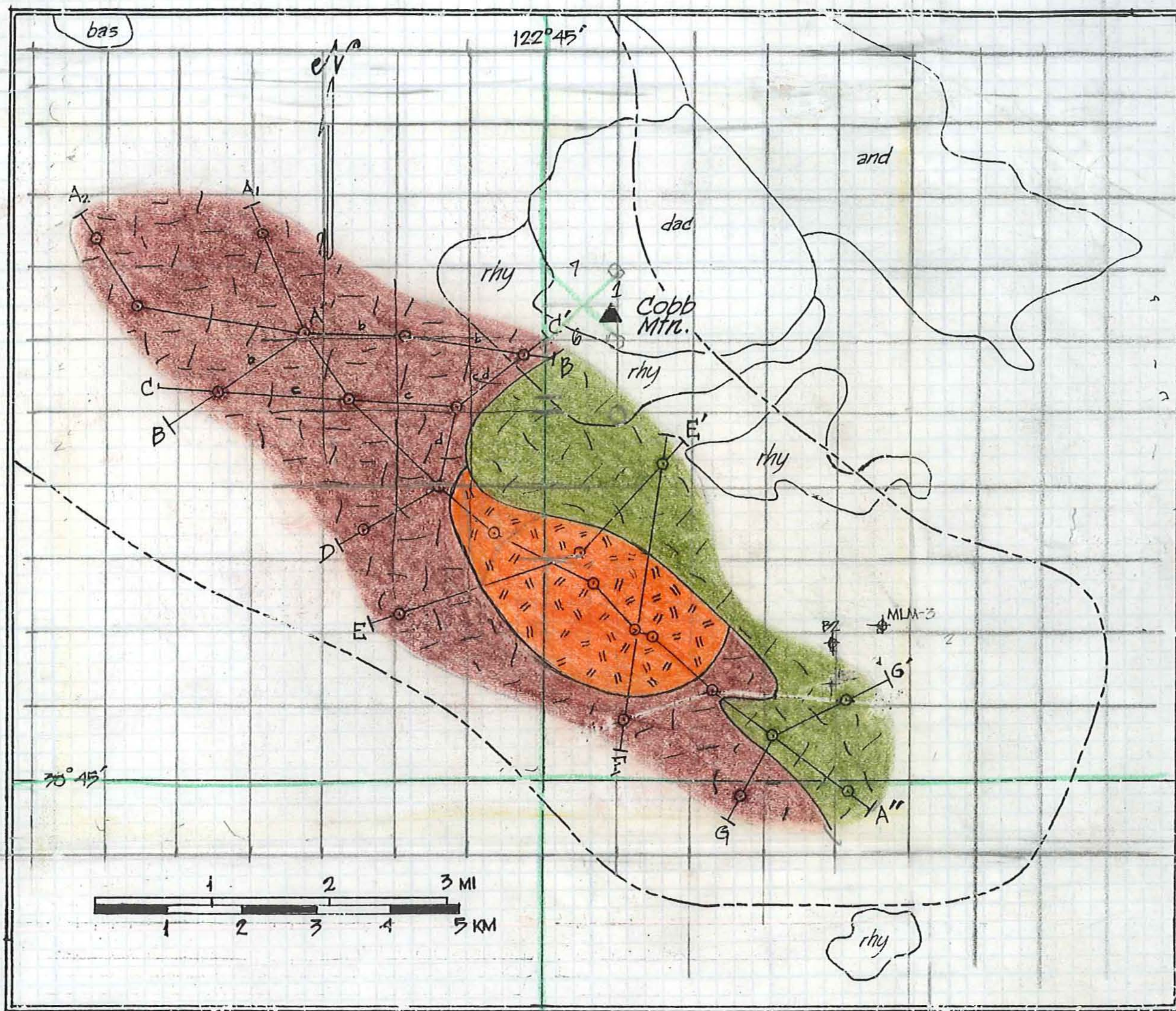
PYROXENE(?)-BIOTITE MICROGRANITE PORPHYRY

PYROXENE-BIOTITE GRANITE

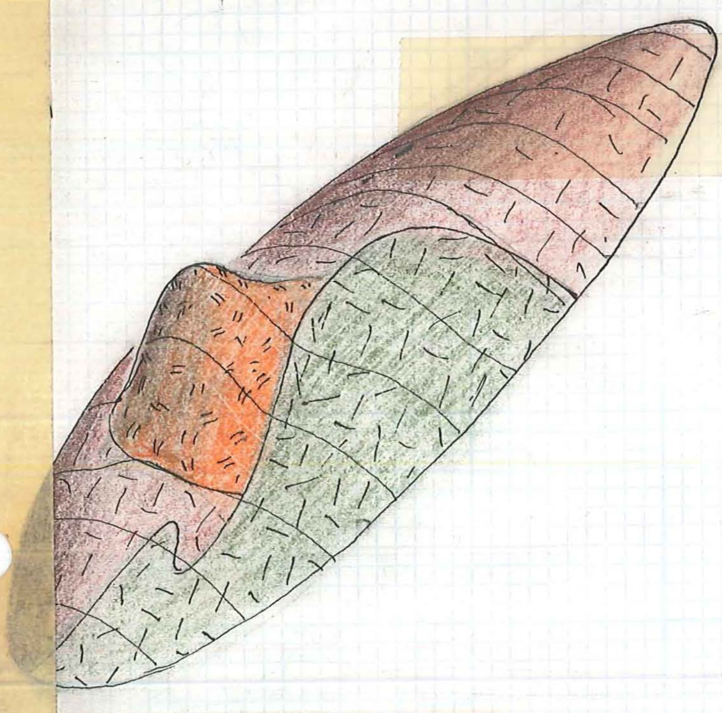
Volcanic rocks of the Clear Lake volcanic field.

and - andesite
dac - dacite
rhy - rhyolite
bas - basalt

DRAFT



J. Hulen 03/96



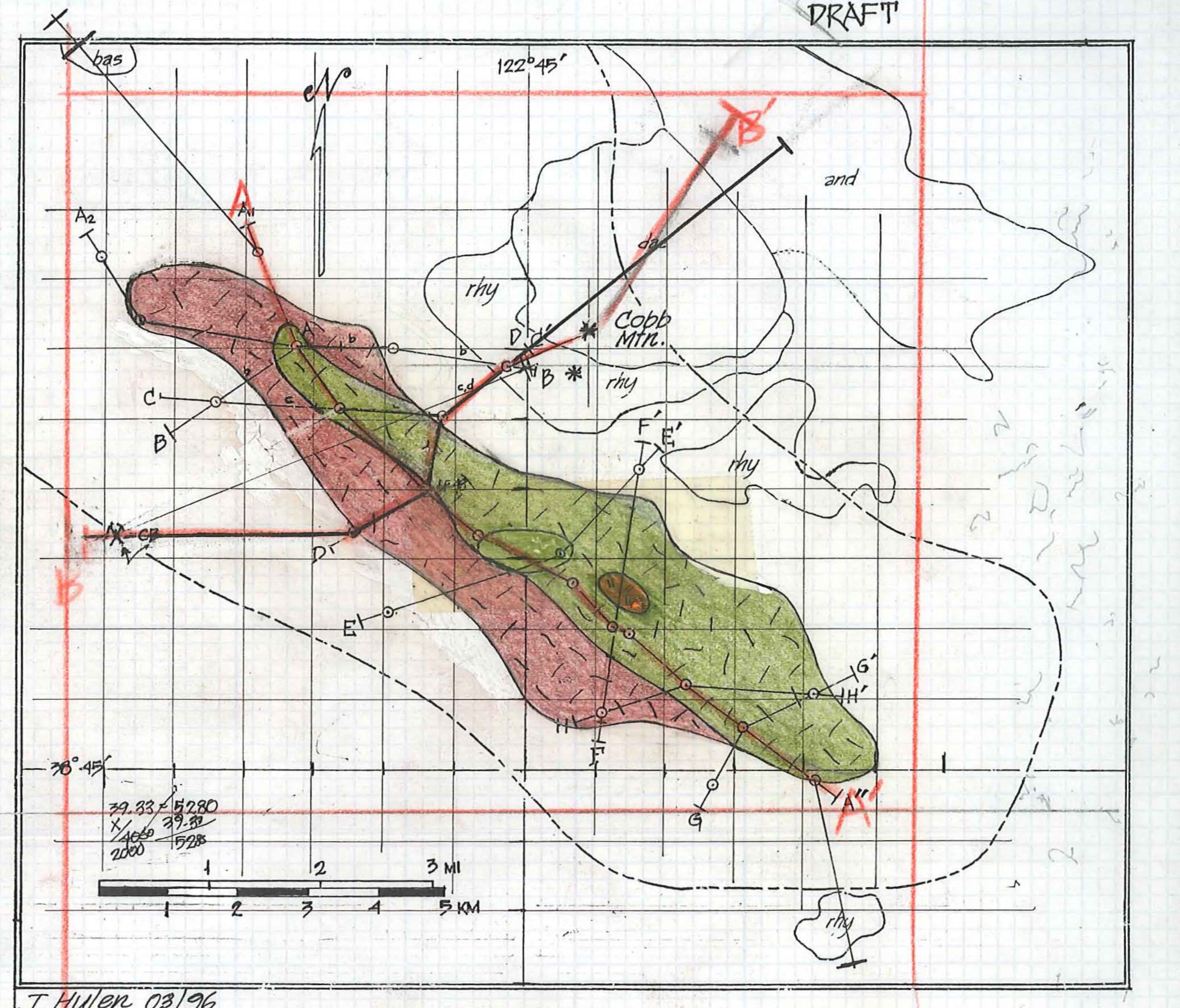
GEOLOGIC MAP, TOP OF THE GEYSERS' PLUTON (convex-upward curved surface)

- PYROXENE-HORNBLENDE-BIOTITE GRANODIORITE
- PYROXENE(?)-BIOTITE MICROGRANITE PORPHYRY
- PYROXENE-BIOTITE GRANITE

Volcanic rocks of the Clear Lake volcanic field

and - andesite
dac - dacite
rhy - rhyolite
bas - basalt

DRAFT



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GEOLOGIC MAP OF THE GEYSERS PLUTON AT ELEVATION (-)1524 m [-5000 ft]

14.89 = 2000'
/60

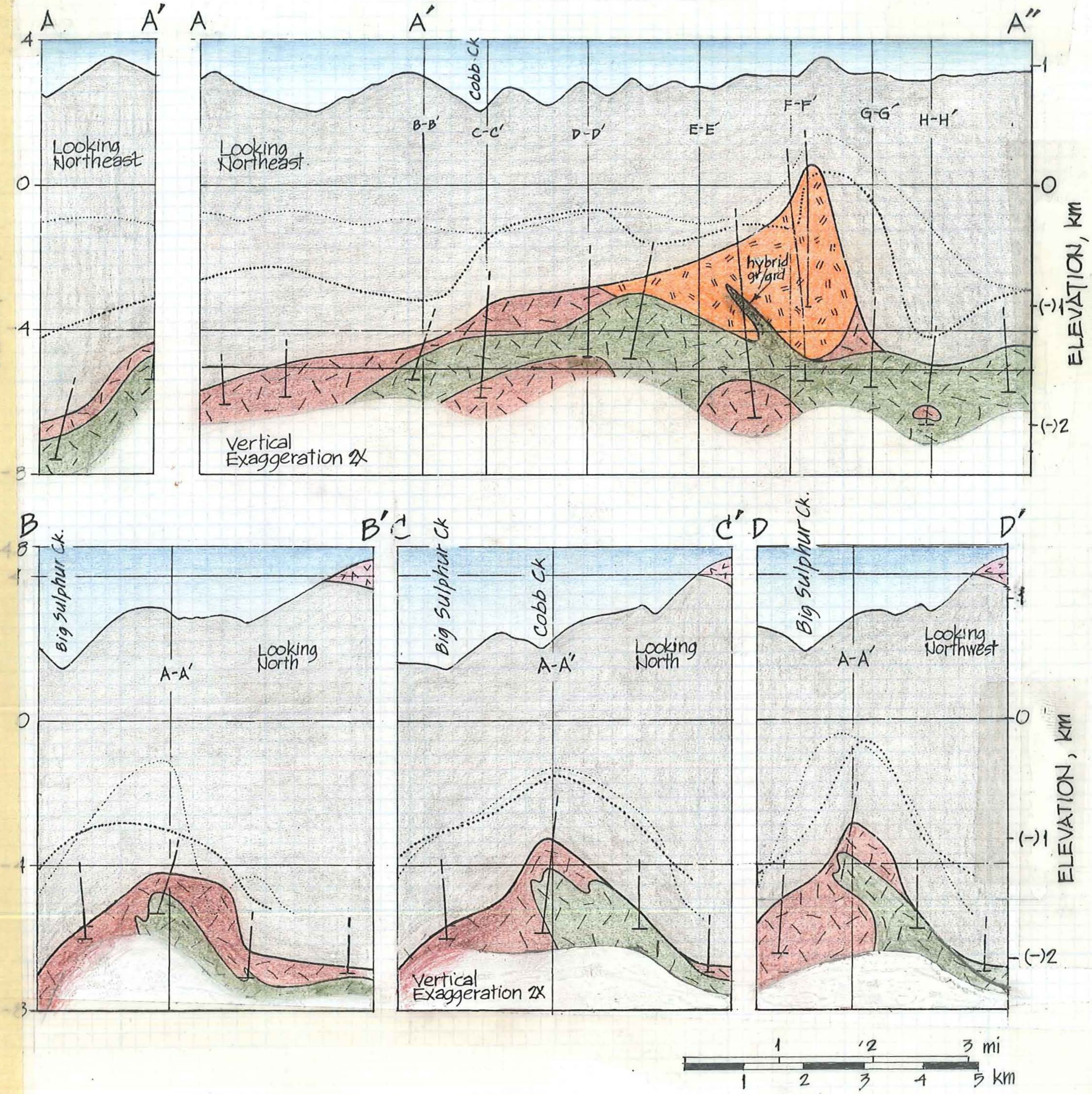
- PYROXENE-HORNBLENDE-BIOTITE GRANODIORITE
- PYROXENE(?) BIOTITE MICROGRANITE PORPHYRY
- PYROXENE-BIOTITE GRANITE

0.25
4.03

Volcanic rocks of the Clear Lake volcanic field

and - andesite
dac - dacite
rhy - rhyolite
bas - basalt

J. Hulen



LITHOLOGIC SECTIONS THROUGH THE GEYSERS PLUTON

Pyroxene(?)-biotite microgranite porphyry [redacted]

Pyroxene-biotite granite [redacted]

Franciscan-assemblage metasedimentary and metavolcanic rocks undivided (late Mesozoic)

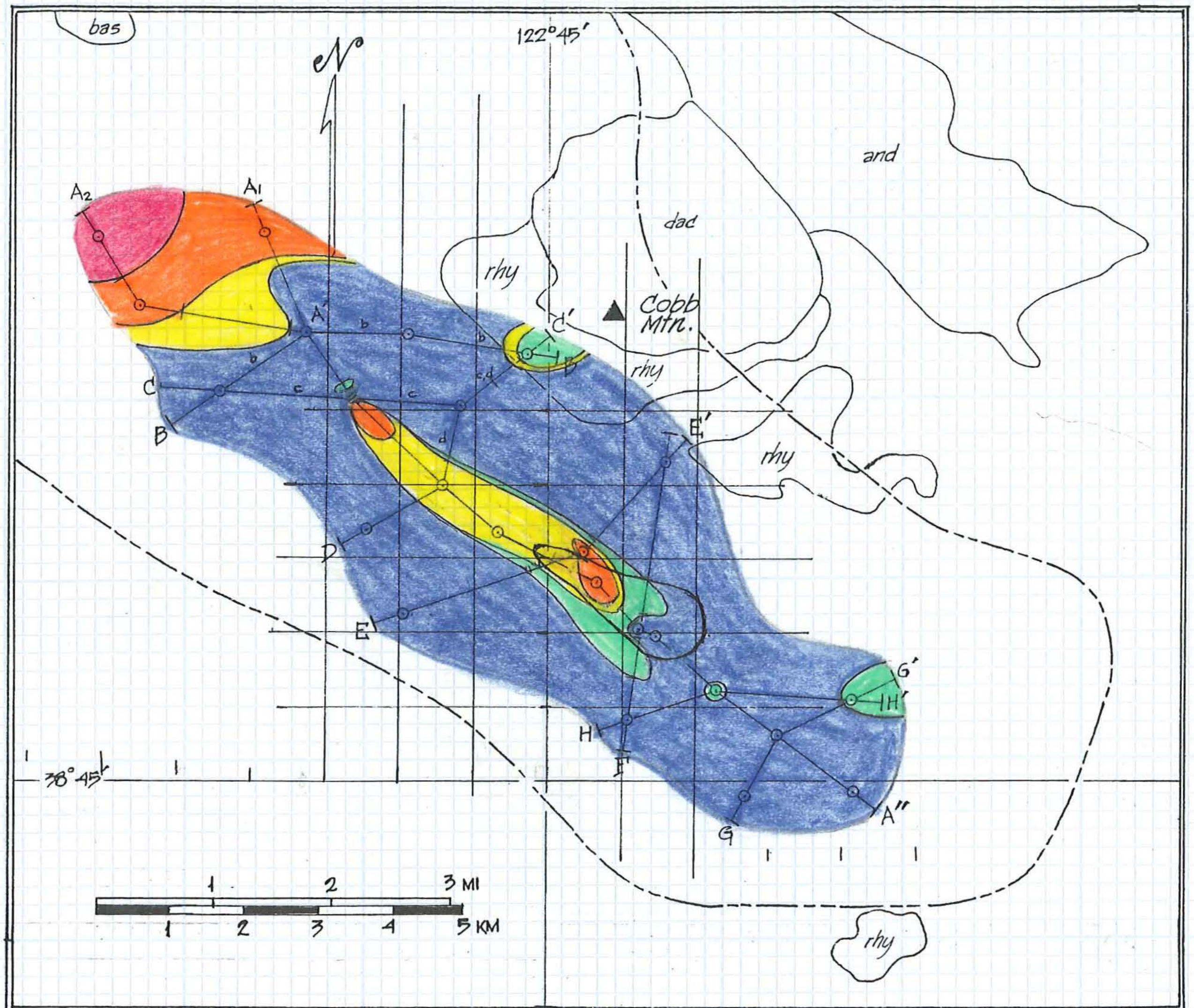
Rhyolite of Cobb Mountain [redacted]

Pyroxene-hornblende-biotite granodiorite [redacted]

Top of steam reservoir in study wells only

Top of steam reservoir in all wells (smoothed contour)

DRAFT



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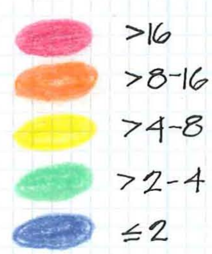
TOTAL BOROSILICATE (WT. %), UPPER 61 m (200 ft) OF THE GEYSERS PLUTON (convex-upward curved surface)



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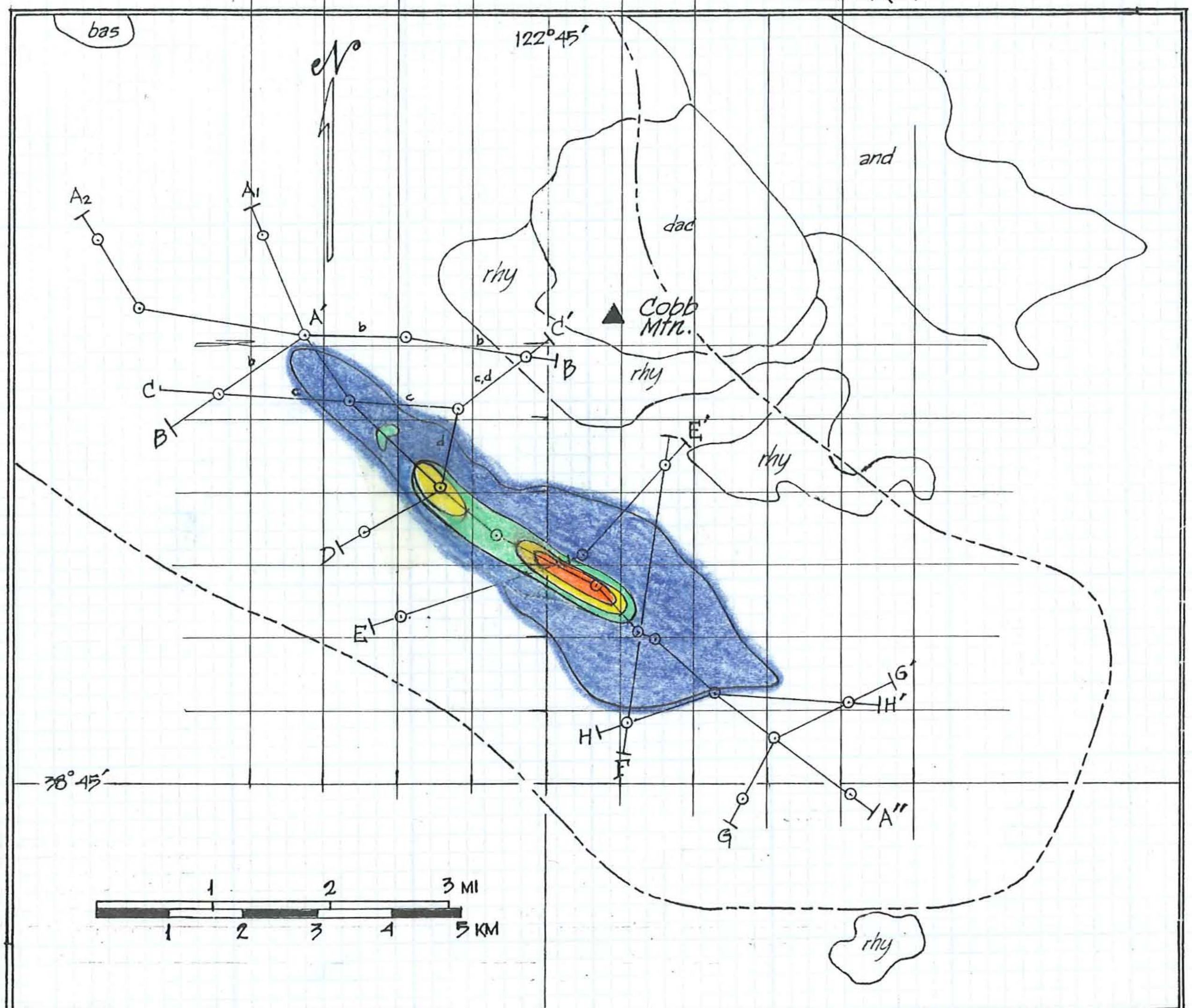

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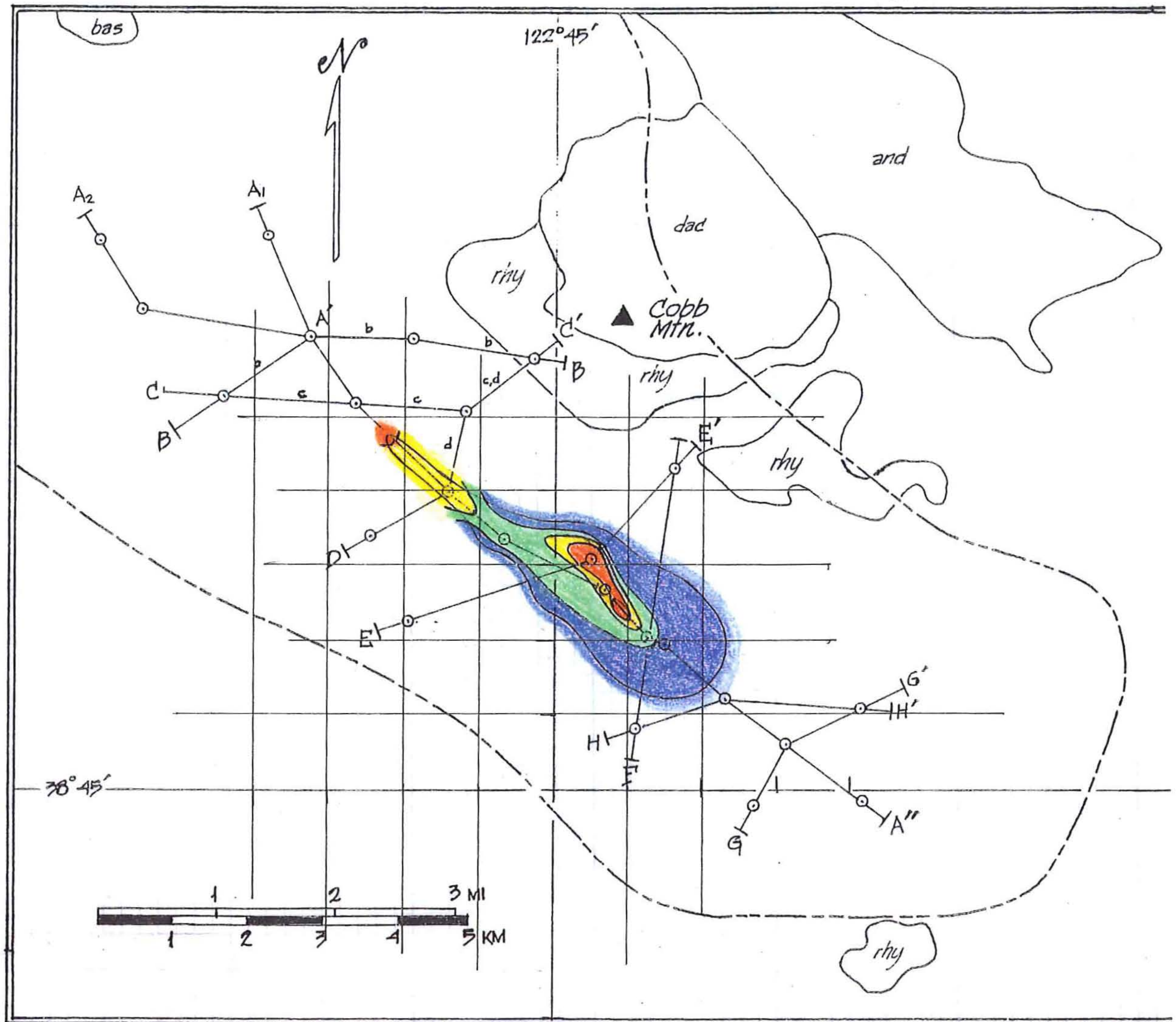
TOTAL BOROSILICATE (WT. %) IN THE GEYSERS PLUTON AND ADJACENT HORNFELS

ELEVATION (−)1219 m [−4000 ft]

- >8-16
- >4-8
- >2-4
- ≤2

DRAFT



J. Hulen 03/96

TOTAL BOROSILICATE (WT. %)
IN THE GEYSERS PLUTON
AND ADJACENT HORNFELS

ELEVATION (-)914 m [-3000 ft]

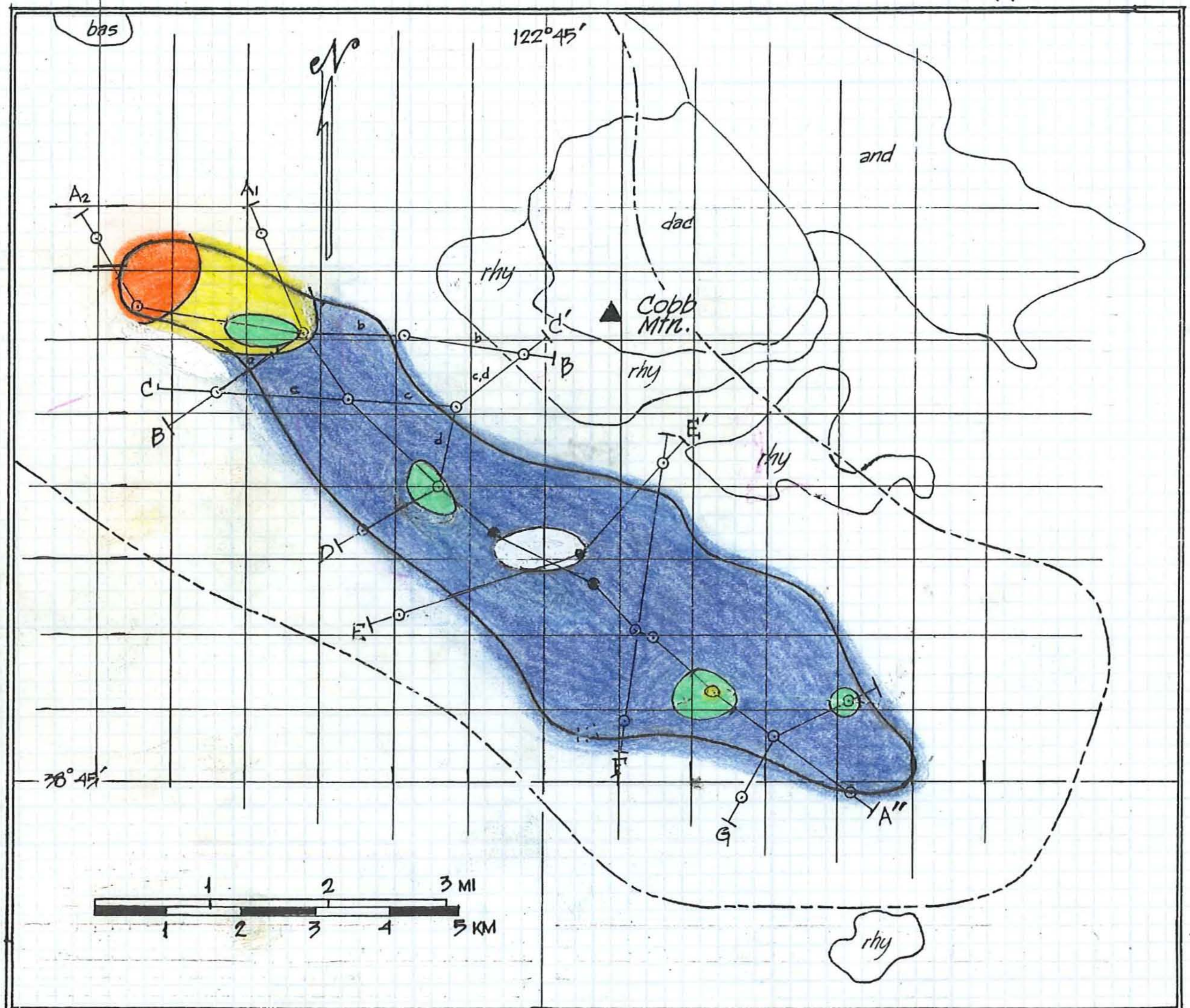
>8-16

>4-8

>2-4

≤2

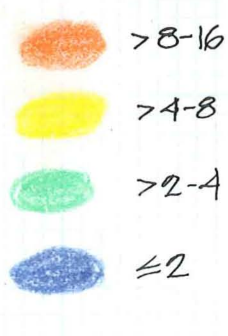
DRAFT



J. Hulen 03/96

TOTAL BOROSILICATE (WT.%) IN THE GEYSERS PLUTON AND ADJACENT HORNFELS

ELEVATION (-)1524 m [-5000 ft]



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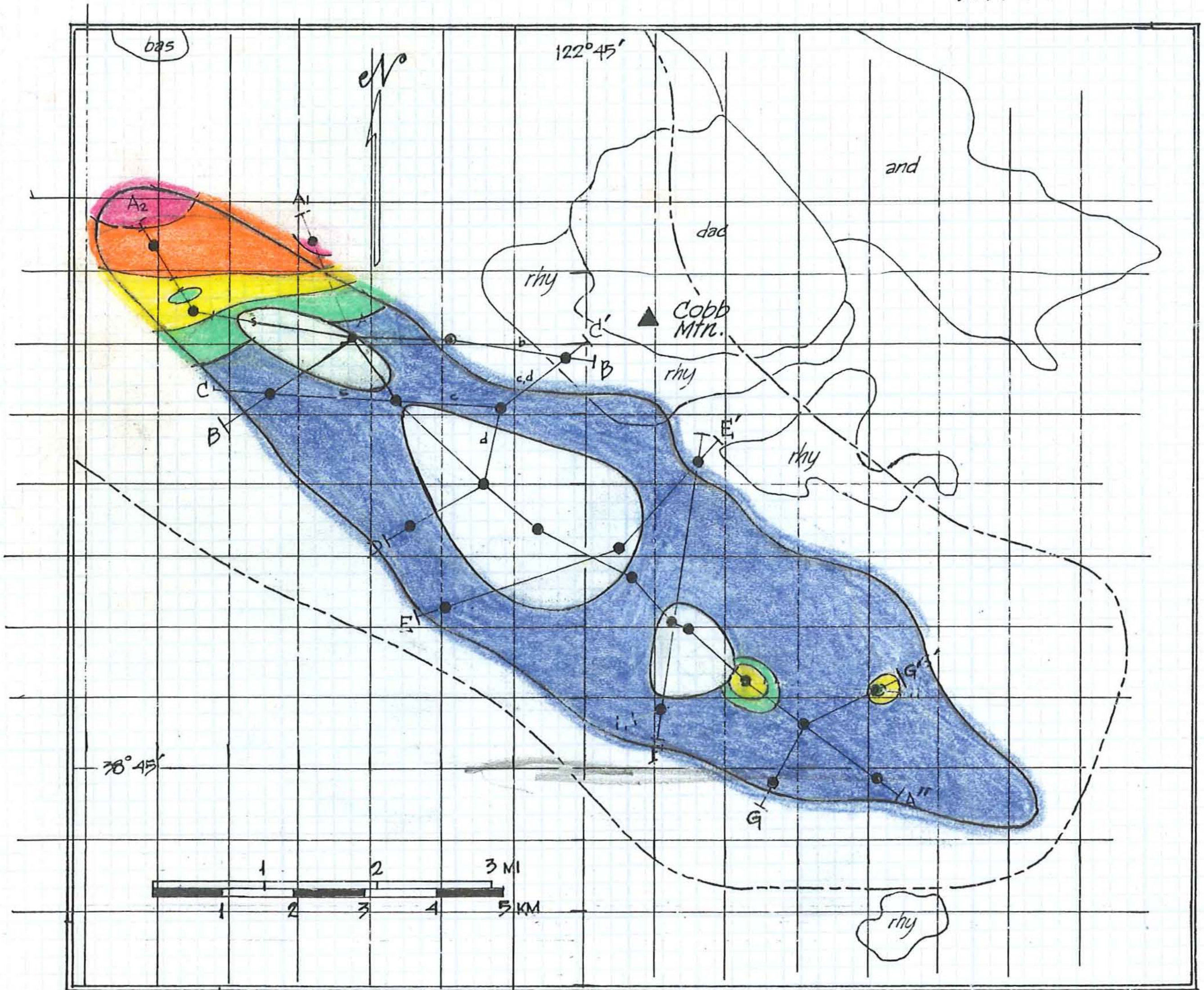

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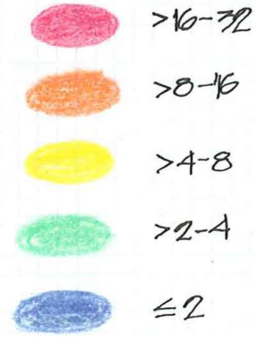
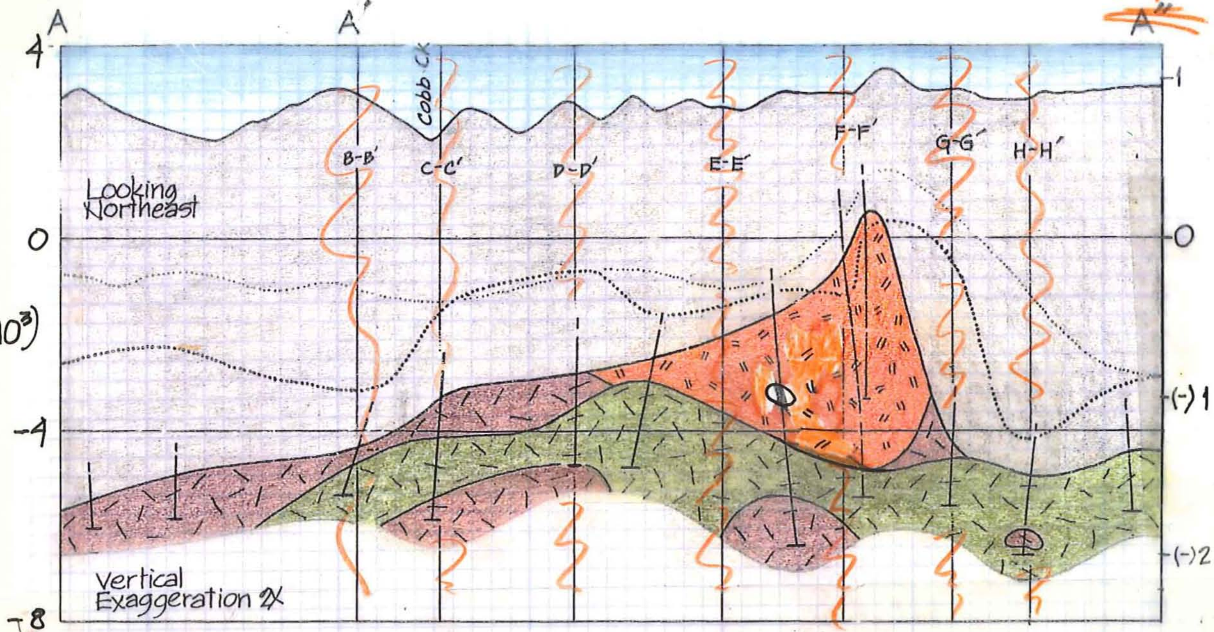
TOTAL BOROSILICATE (WT.%) IN THE GEYSERS PLUTON & ADJACENT HORNFELS

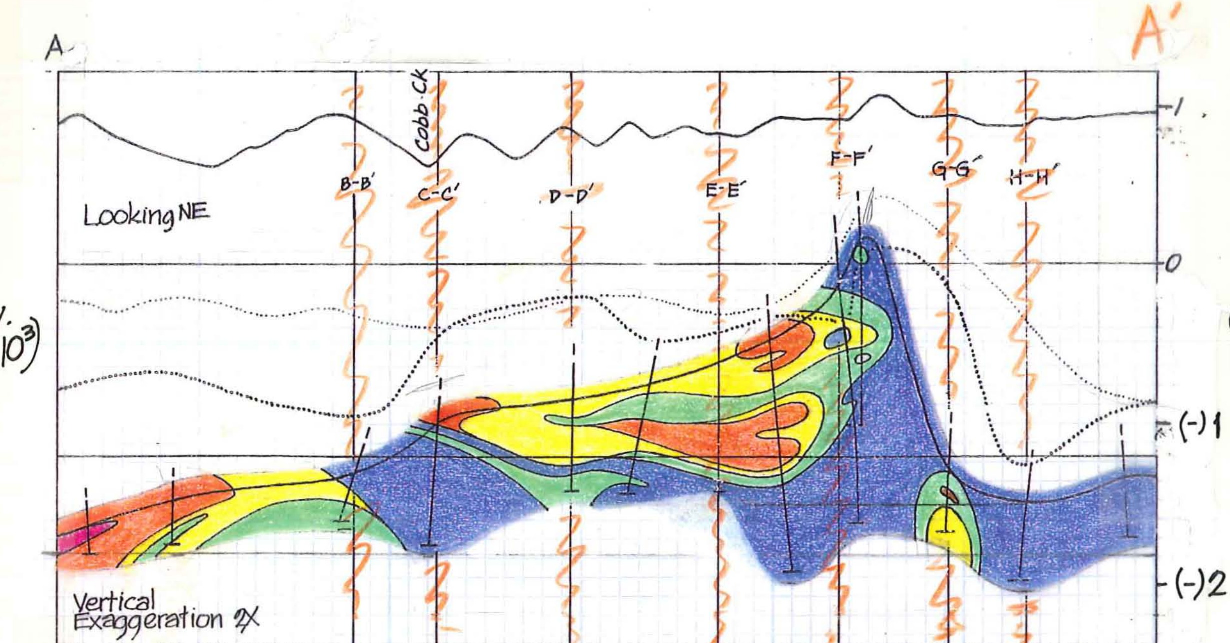
ELEVATION (-)1829 m [-6000 ft]



Bob - please add steam entries



GEOLOGIC SECTION*



BOROSILICATE-ENRICHMENT CROSS SECTION*

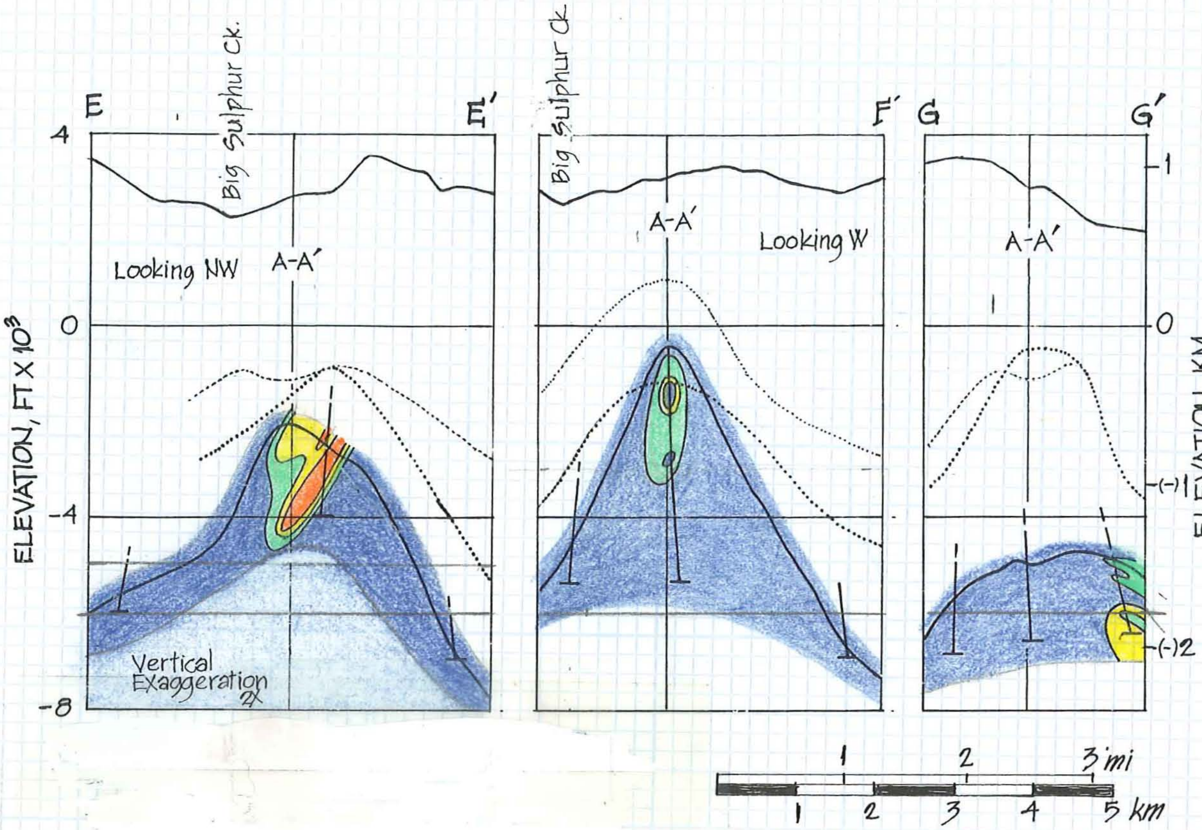
* See Figure for explanation of symbols

Top of steam reservoir (study wells only)

Top of steam reservoir (smoothed; from Unocal et al., 1989)

Major steam entries (≥10 psi pressure increase during drilling)

Figure . Longitudinal geologic and borosilicate-enrichment cross sections through The Geysers pluton.



CROSS SECTIONS THROUGH THE GEYSERS PLUTON SHOWING DISTRIBUTION OF BOROSILICATES

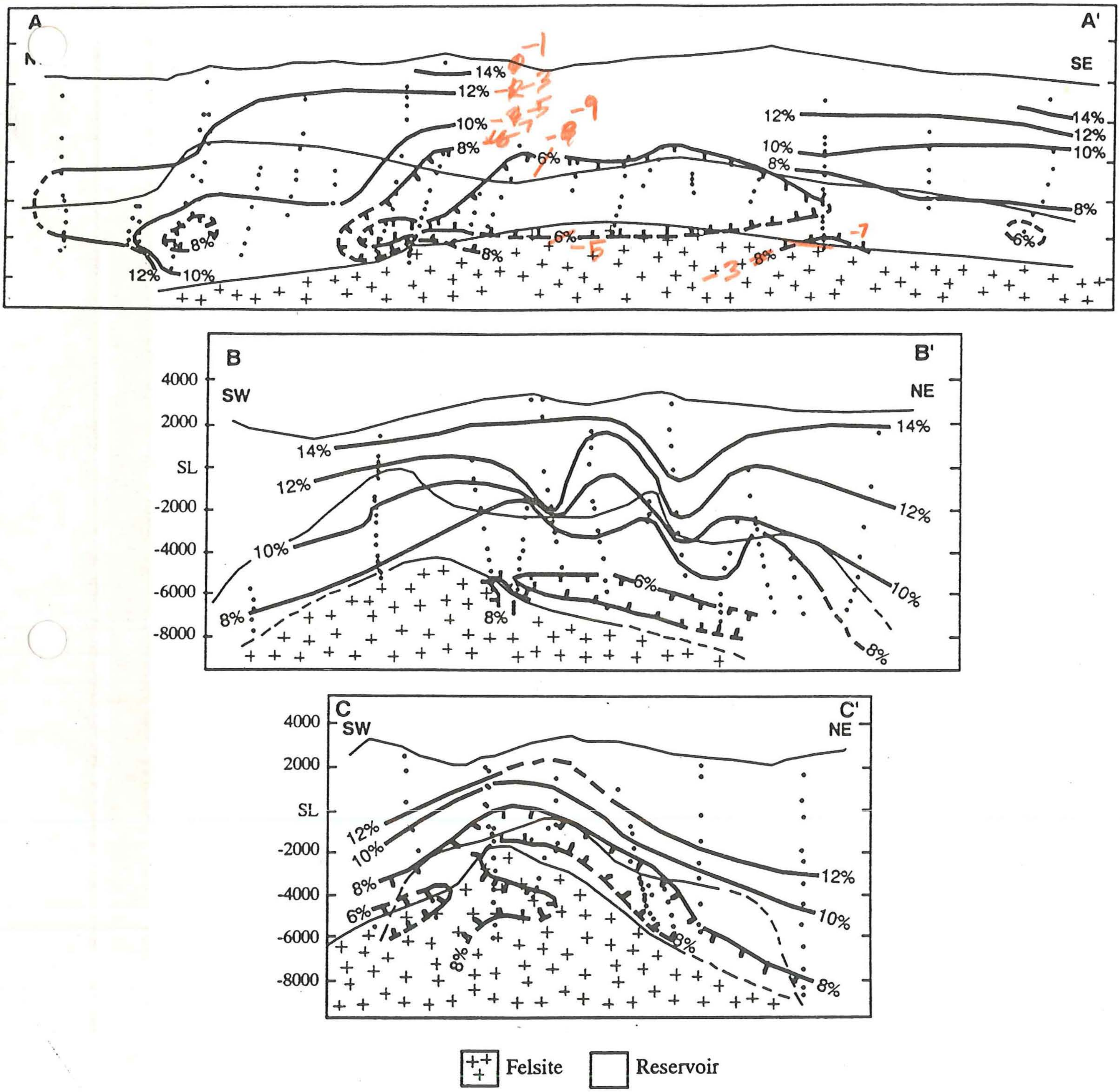
WT% TOURMALINE PLUS FERROAXINITE

- >8-16
- >4-8
- >2-4
- ≤2

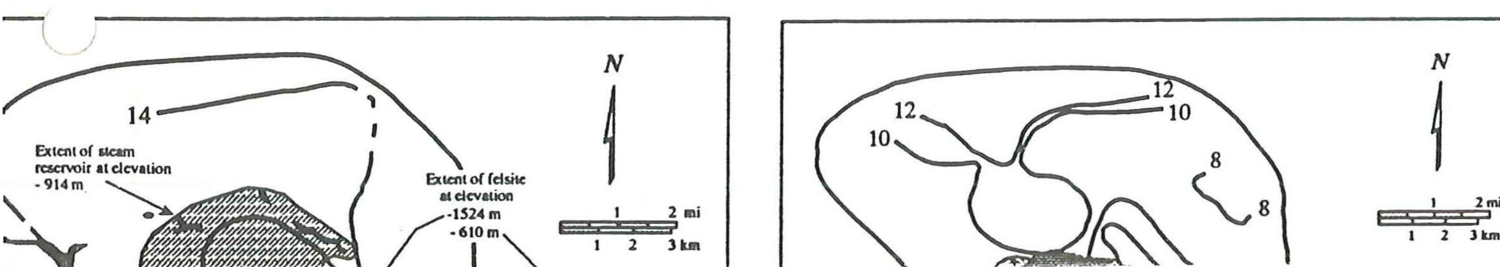
Top of steam reservoir in study wells only

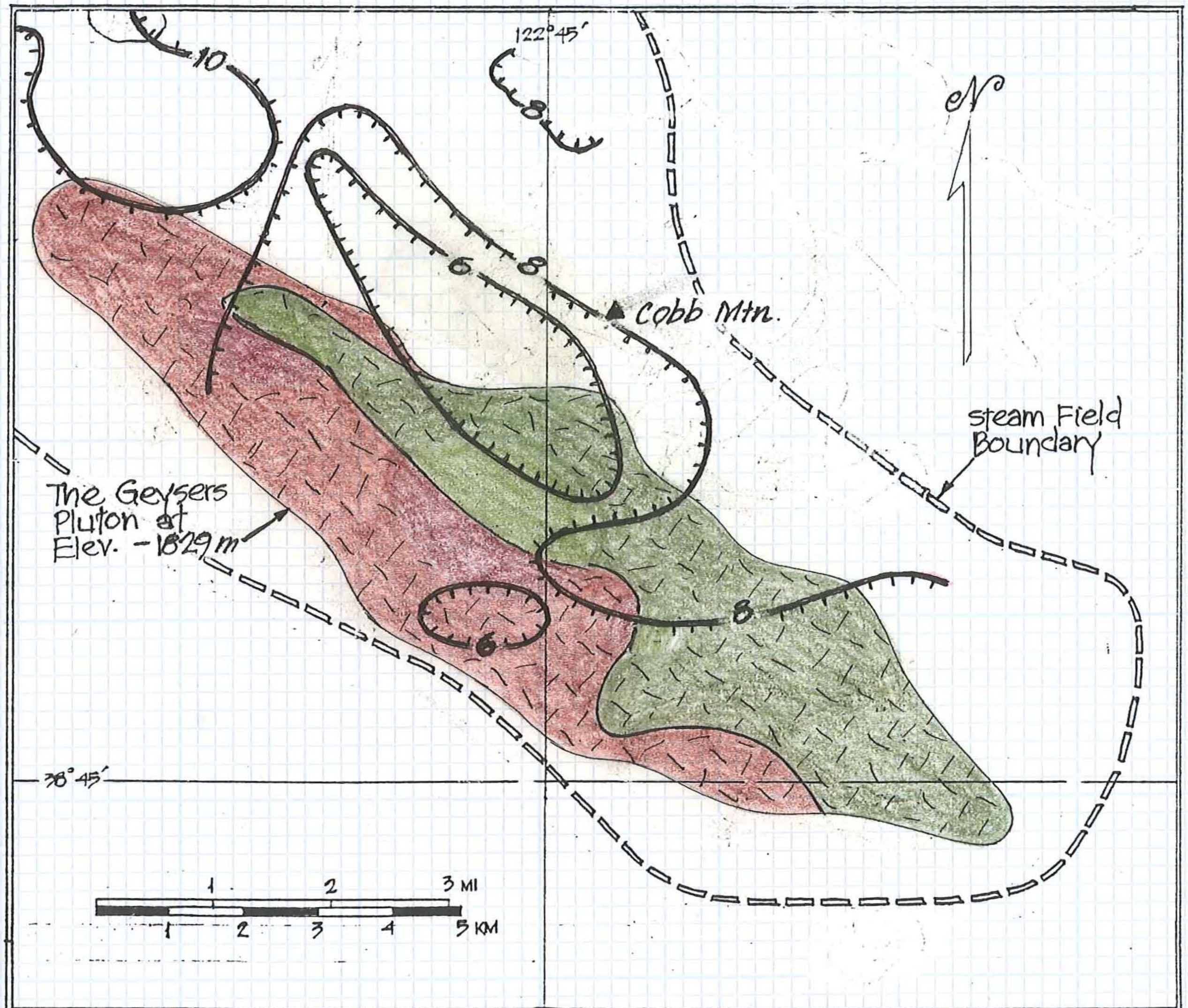
Top of steam reservoir in all wells (smoothed contours)

* FOR A-A′ SEE "GEOLOGIC SECTIONS"



re 4. Cross sections through The Geysers field showing the distribution of $\delta^{18}O$ values in per mil with respect
: top of the steam reservoir and the felsite. All values were contoured in this figure. See Figure 3 for cross sec-
ocations.





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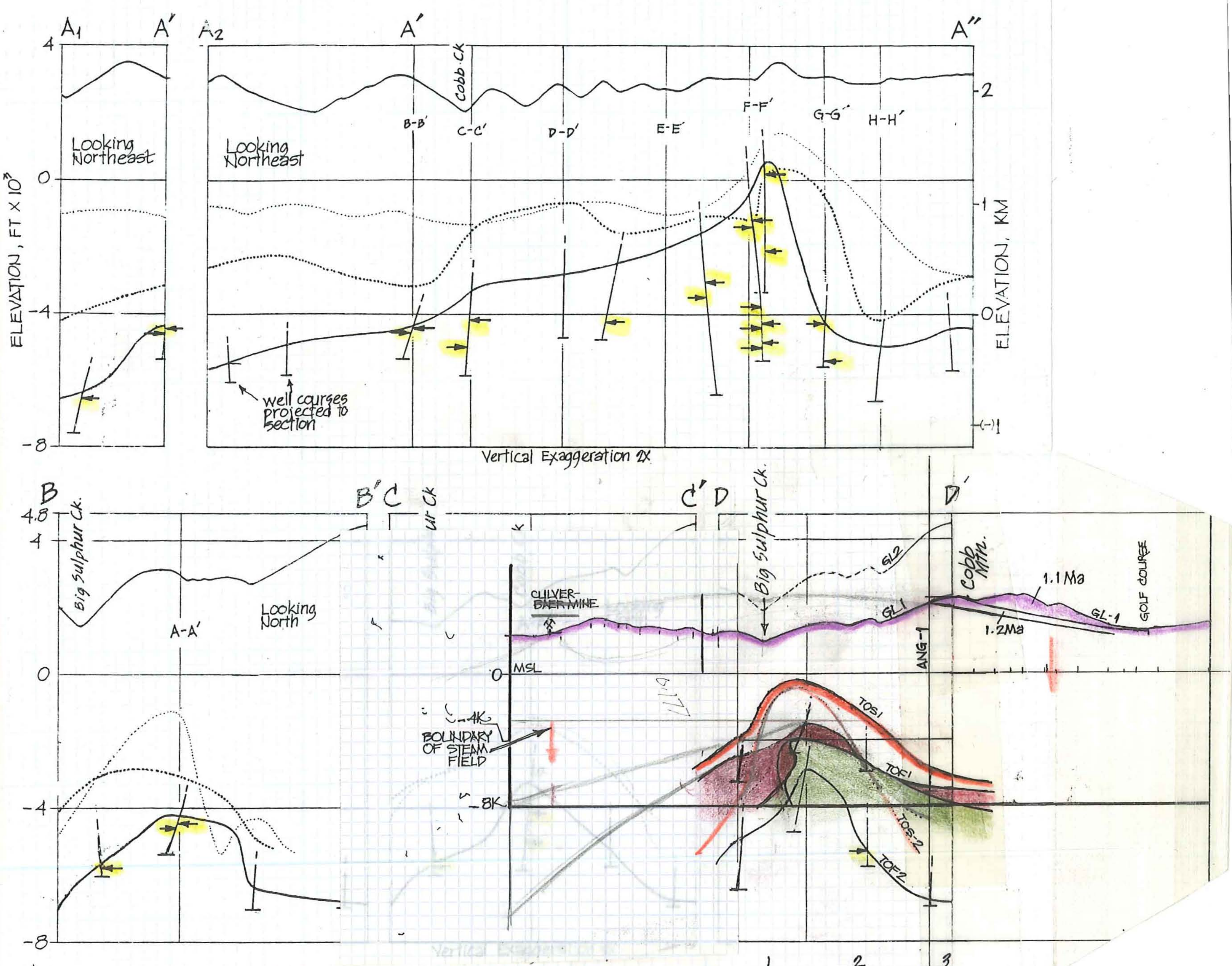
WHOLE-ROCK $\delta^{18}O$ VS PLUTONIC ROCK TYPES

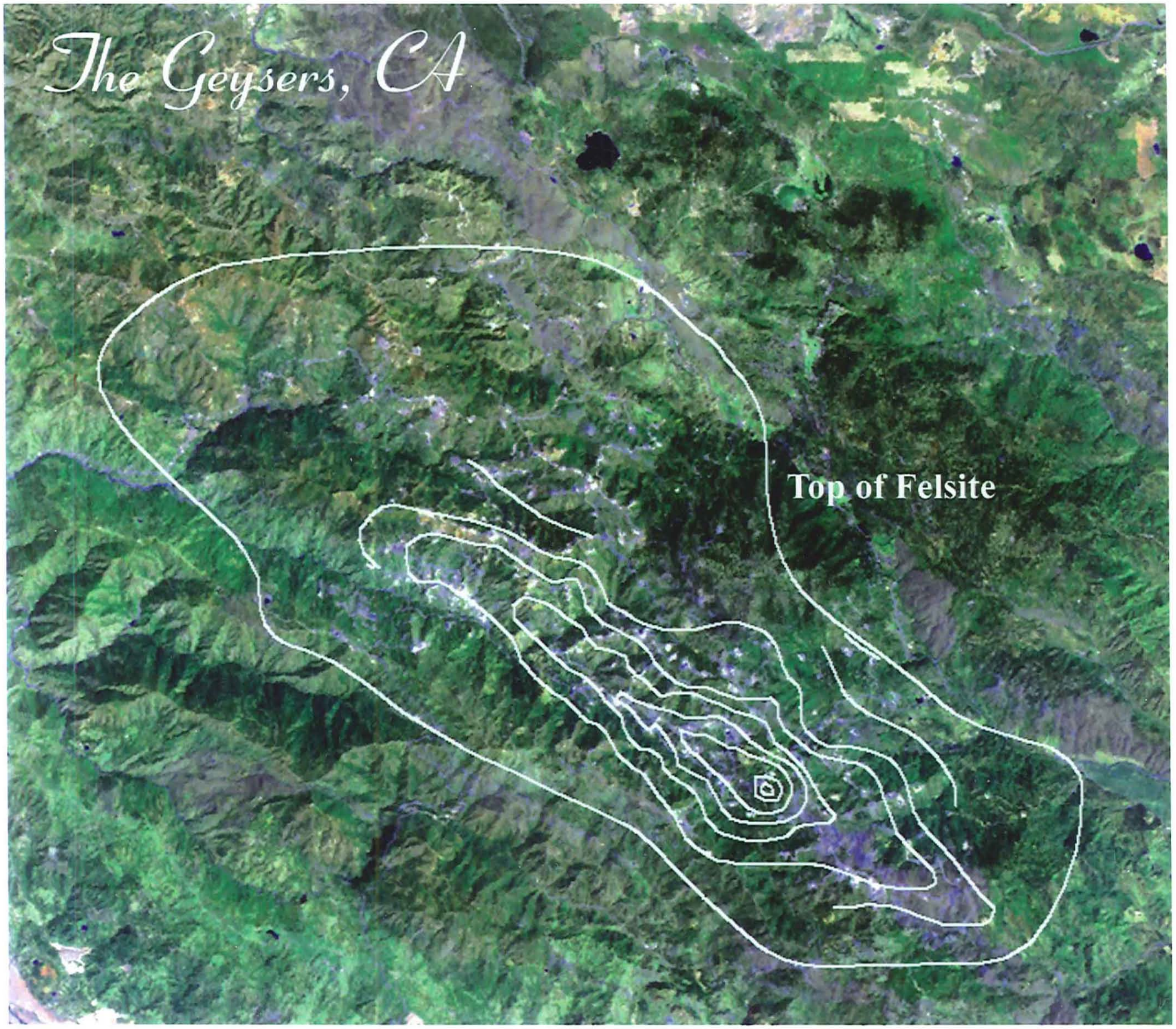
6 — Average $\delta^{18}O$ values (‰), elevation -1219 m to -1829 m (Moore and Gunderson, 1995)

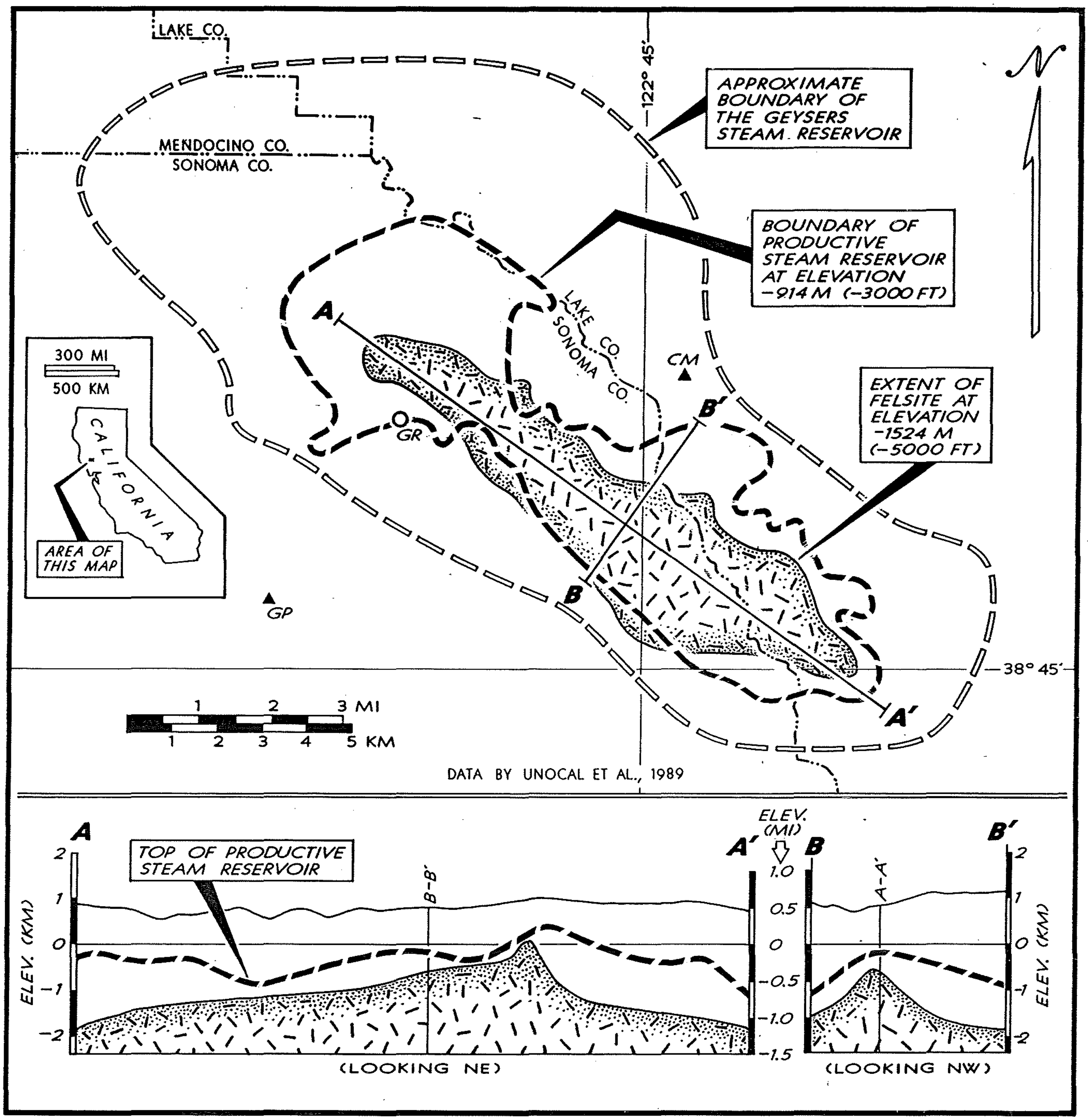
Granodiorite
Granite
} Plutonic rock types at elevation -1829 m



STEAM ENTRIES* IN THE GEYSERS PLUTON

* ≥ 10 psi pressure increase during drilling


The Geysers, CA
Top of Felsite



Slides 11 and 12 (substitute--illustrations corresponding to the actual slides are not available). Generalized map and cross sections illustrating close correlation of The Geysers geothermal system and a deeply concealed, Plio-Pleistocene, felsic intrusive complex (the "felsite"; Schriener and Suemnicht, 1981). Data from Unocal et al., 1989. In the Northwest Geysers, where our lithologic, structural, and alteration research have been concentrated since 1990, the outer limits of the present-day steam field closely correspond with the boundaries of a high-temperature alteration halo developed under liquid-dominant conditions around and above the felsite immediately prior to evolution of the current steam field.