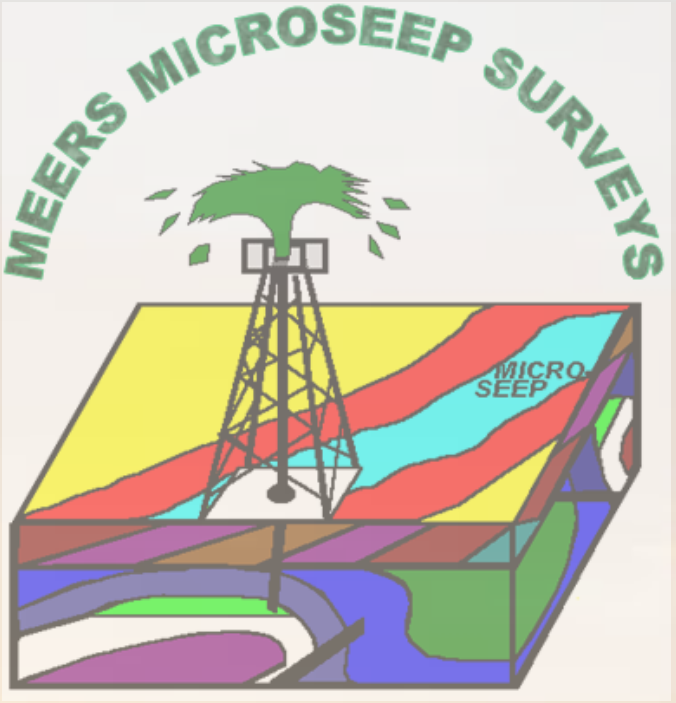
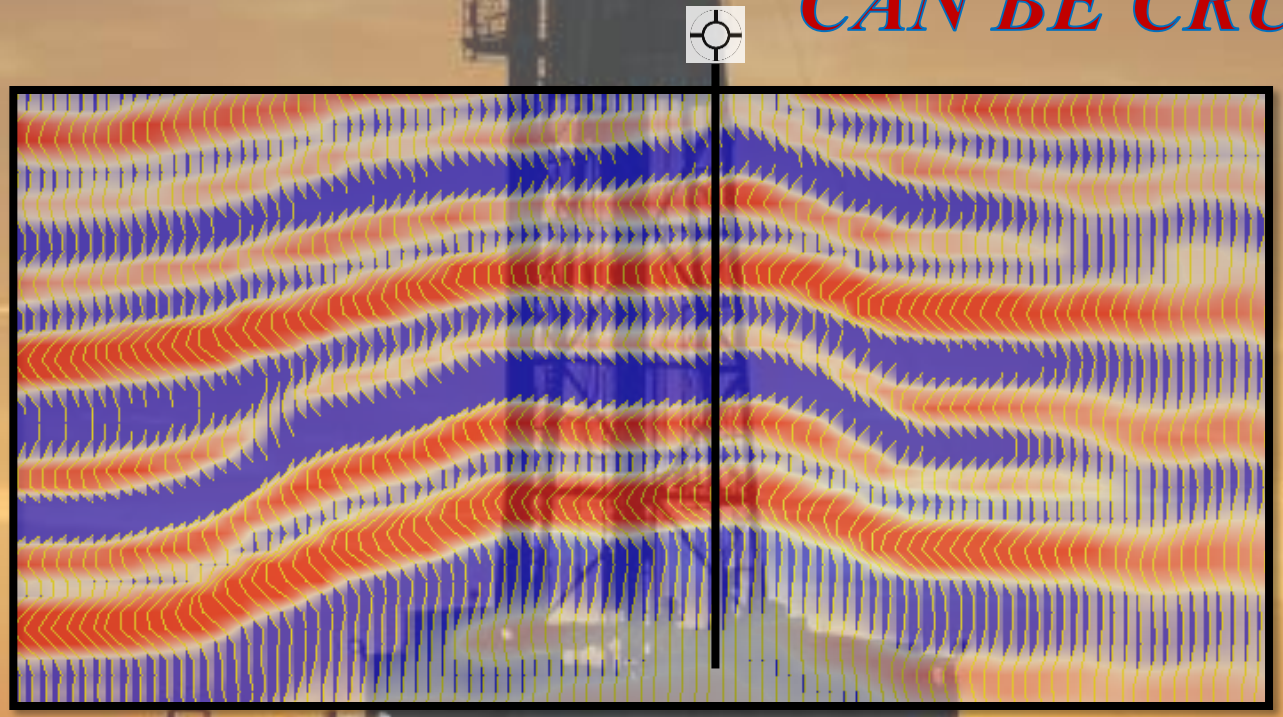
GEOCHEMICAL SURVEYS



THE ADDED DIMENSION

TRADITIONAL EXPLORATION
DRILL THE REEF

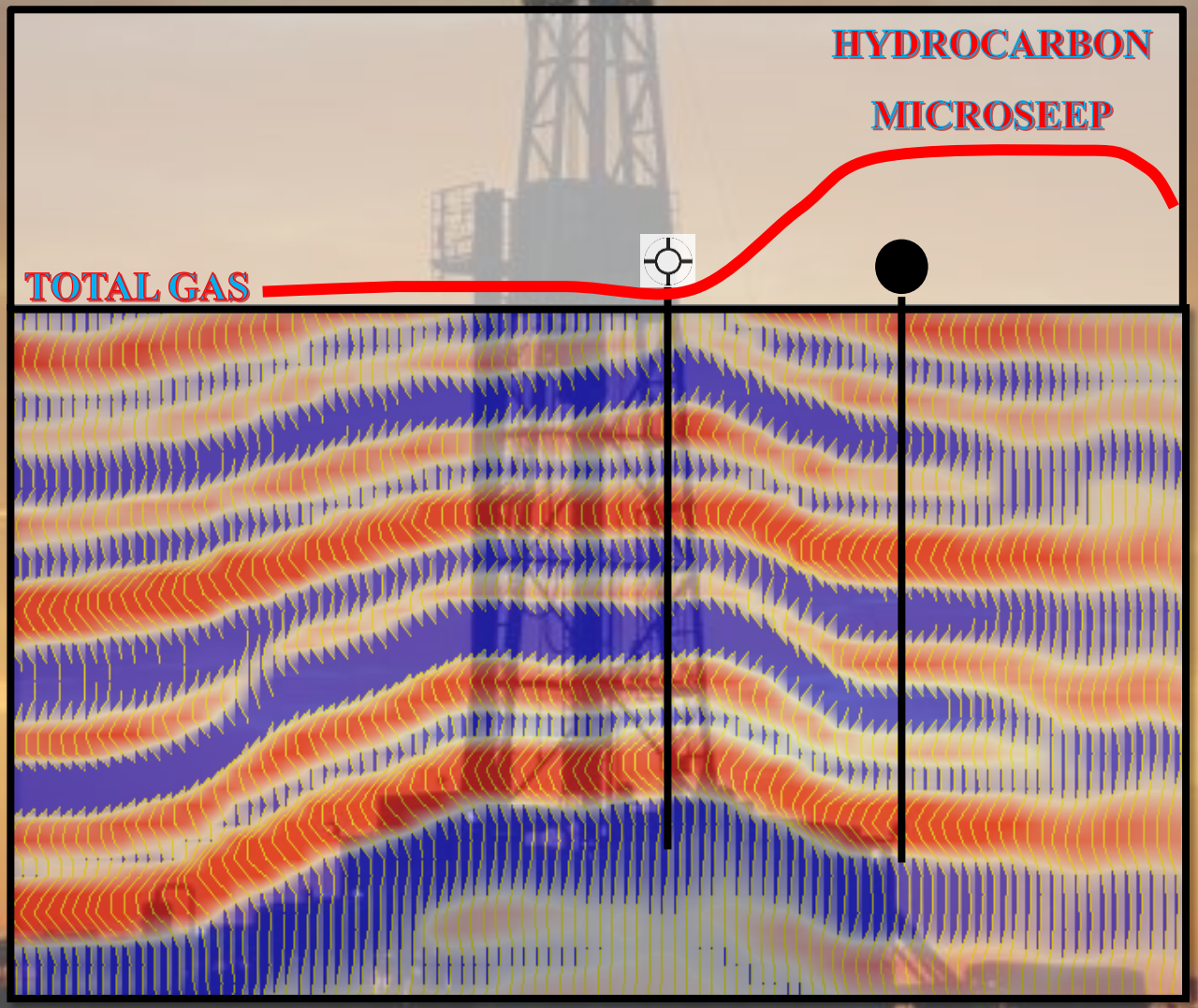
MOTHER NATURE CAN BE CRUEL



SHOOT; REPROCESS; RESHOOT

HYDROCARBON MICROSEEPAGE

THE ADDED DIMENSION TO AN EXPLORATION PROGRAM

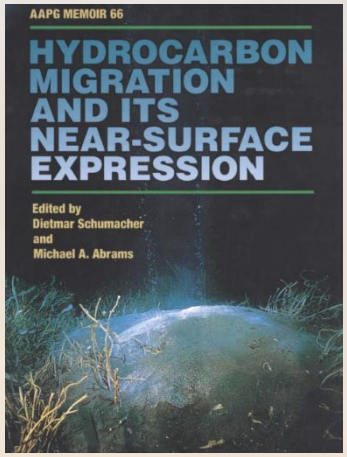


Hydrocarbon traps are *changes* in permeability in both vertical & lateral directions, not the absence of permeability. The trap is due to the buoyancy of hydrocarbons and a restriction to migrate both vertically and laterally.

Microseeping hydrocarbons wait their turn to migrate through the tiny microfractures toward the surface.

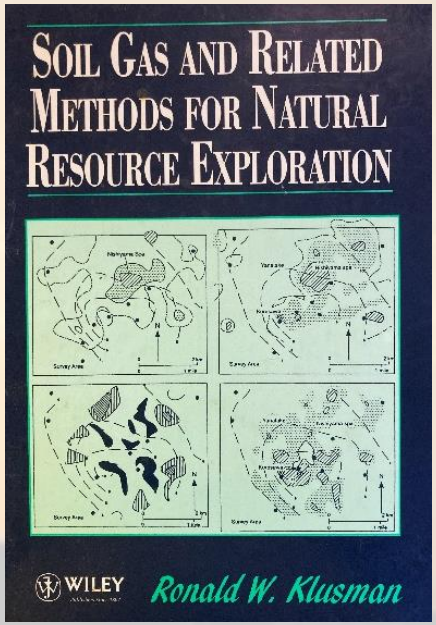
MICROSEEP AS AN EXPLORATION TOOL

Publications such as "Hydrocarbon Migration And Its Near-surface Expression" published by the American Association of Petroleum Geologist, Memoir 66, detail hydrocarbon microseepage as a strong tool in finding hydrocarbon accumulations. Contributions by Conoco Inc., Pennzoil, Exxon, Phillips, and Shell show the attention the major oil companies give to hydrocarbon microseepage in their exploration programs.



"Soil Gas and Related Methods for Natural Resource Exploration" by Ron Klusman PhD, Colorado School of Mines.

"Contrary to popular belief that 'hydrocarbon reservoirs absolutely do not leak', a large quantity of evidence has accumulated, indicating that gases can be transported from the depths of an oil and gas reservoir to the surface without significant dilution and dispersion."



MICROSEEP DETECTION METHODS

DIRECT

Poor Repeatability due to atmospheric conditions and soil moisture changes. Concentration changes due to soil clay content.

Soil Gas

Measured at depth (3-10 feet)

Gas Chromatograph – laboratory measurement from field sample

Photo Ionization Device – very portable measured in field

Significant anomalies (20X-40X background) are indicative of pressured reservoirs.

Radar

(methane clouds)– Affected by cultivation and rainfall

Geo-Microbial Inc.

Butane consuming micro bacteria living in soil.
Noisy measurements requiring tight grid and smoothing.

MICROSEEP DETECTION METHODS

INDIRECT - Good Repeatability

Indirect measurement of chemical alteration of soils due to hydrocarbon microseepage.

-Magnetic Susceptibility

-Radiometric analysis

-Trace element concentration

-Landsat: Tonal & Bleached anomalies

-Temperature = Gas Volume X Pressure affected by soil permiability, soil ground cover & sun. Extremely noisy.

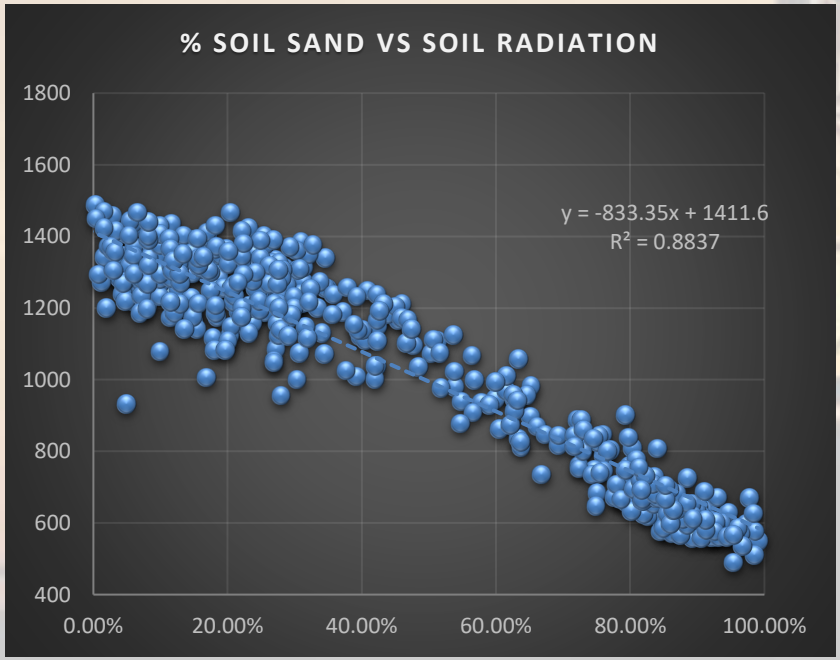
MICROSEEP DETECTION METHODS

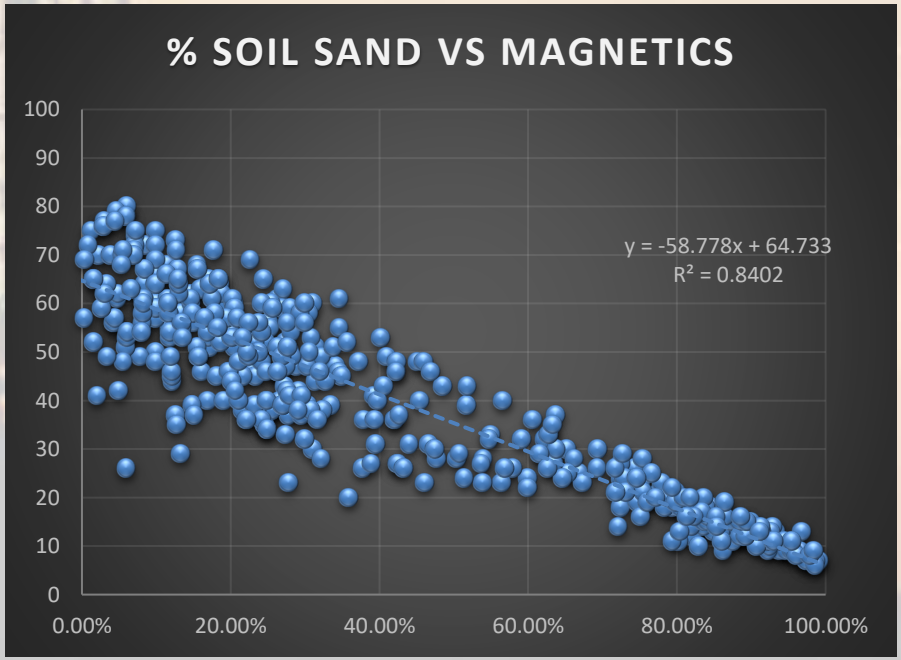
DATA CORRECTIONS

All soil collected data, including interstitial soil gas, needs corrected for clay content.

Interstitial soil gas volumes should be corrected for an increase in drill bit temperature due to high clay content. Volume = Temperature / Pressure

Sand content in soil samples can be calculated using sieves & scales among many other methods.





MINEROLOGY OF A MICROSEEP

Hydrocarbons in the near surface react with sulfates in groundwaters to produce Caliche, Hydrogen Sulfide, & water (Kartsev et al., 1959)

$CH_4 + CaSO_4 = CaCo_3 + H_2S + H_2O$
Methane + Gypsum = Caliche + Hydrogen Sulfide gas + water

Caliche is a good fossil indicator of hydrocarbon microseepage.

Caliche can be visually seen and roughly quantified by site. It is accurately quantified using XRF or XRD devices.

It is also indirectly seen using radiometric devices or using Iodine, Bromine, Strontium, & Uranium.

Partial cause of Landsat "Tonal" & "Bleached" Anomalies.

CALICHE DUG FROM BOTTOM OF MUD PIT AT PRODUCING WELL SITE. – NOT ALL CALICHE IS VISIBLE AT SURFACE

MINEROLOGY OF A MICROSEEP

Hydrocarbons are antioxidants. In the near surface they cause a chemically reducing environment that induces several chemical changes in the soils that can be detected and measured with several instruments.

DELTA C (Duchscherer)

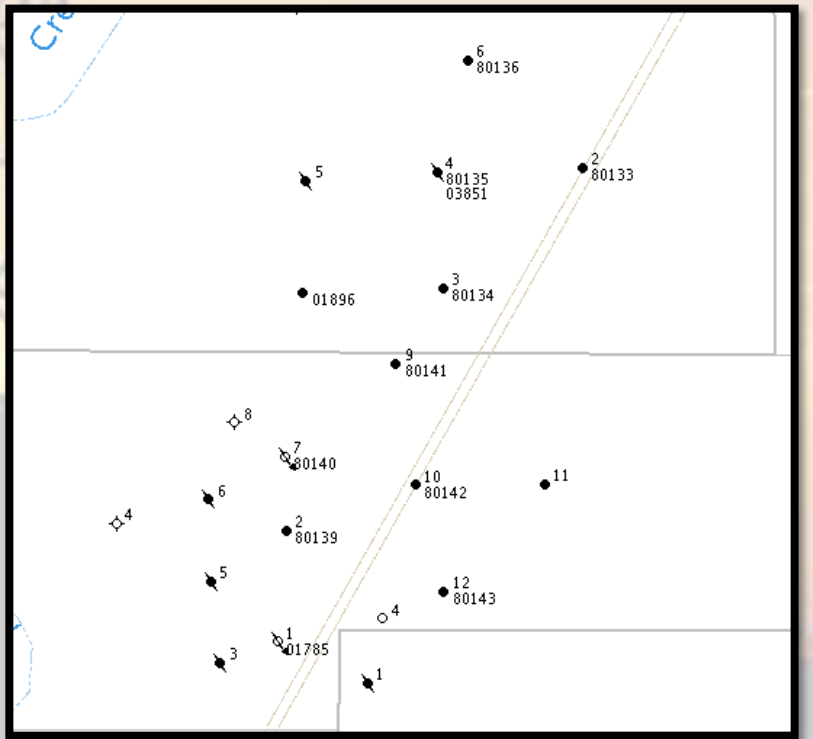
This method of microseep detection is based on oxidizing hydrocarbons producing CO_2 that reacts with calcium to produce $CaCO_3$ with ferrous iron incorporated into the carbonate latus as Ferroan Calcite $(Ca\ Fe)CO_3$. It is measured by ***thermal dissociation*** of carbonates in the soil sample.

Slow and expensive measurement.

Geochemical Surveys used this method and discovered several million barrels of oil in the Abilene area from the 1940's.

Geologist Charles Passel, inventor of the wind chill factor, was the chief geologist. He stated most anomalies were "Halo" geometry.

Caldwell Ranch Field
Taylor County Texas
1 million barrels of oil
15 wells
Tannehill formation
1800 feet deep



MINEROLOGY OF A MICROSEEP

MAGNETIC SUSCEPTIBILITY – MY FAVORITE TOOL

Soils saturated with hydrocarbons will develop high magnetism due to the high sulfur and the reducing environment precipitating pyrrhotite, a magnetic minerals.

Areo-magnetic surveys will see this strong magnetism in the near surface using short wave filters.

Very high magnetic susceptibility measurements have been found in drill cuttings over producing fields as compared to nearby dry holes.

Magnetic anomalies are a good indicator of Methane!

Magnetic Susceptibility anomalies and drill results in Eastern Colorado by Foote & Long, 1988

Magnetic Anomaly	Oil & Gas Well		Dry Hole		
	In Field	On Edge	On Edge	Isolated	Total
Absent	4	3	24	47	78
Present	74	0	9	7	90
Total	78	3	33	54	168

MINEROLOGY OF A MICROSEEP

Radiometric Analysis – Potassium / Bismuth ratio & Total Count

Uranium and potassium are soluble and react to hydrocarbons in the soil. Thorium is immobile and stays constant in the soil profile. Depending on the climate, Uranium will increase in arid soils or decrease concentration in wet soils over oil and gas fields. Potassium always decreases over oil and gas fields while Thorium stays the same. The Ratio of K40 to Tl208 shows the relative concentration of potassium and the ratio of Bi214 to Tl208 will give that relative concentration of uranium. Low potassium anomalies and high uranium ratios in arid climates are good indicators of microseepage.

NURE DATA:

% Each time a flight line crossed an oil or gas field.

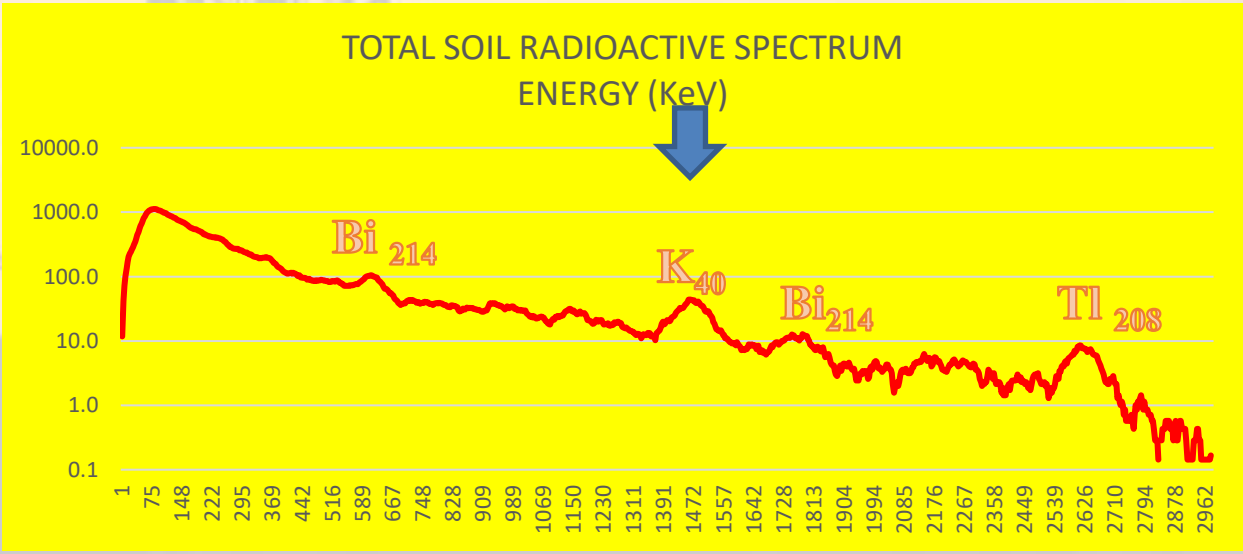
Saunders 1987

Anomaly	East Texas	West Texas
Low K	65%	76%
Low U	63%	
High U		76%
Low K + Low U	47%	
Low K + High U		61%
None	19%	10%
Total		

LOW TOTAL COUNT ANOMALIES

Attributable to high caliche replacing radioactive clay content.

Caution that it is not due to sand content.

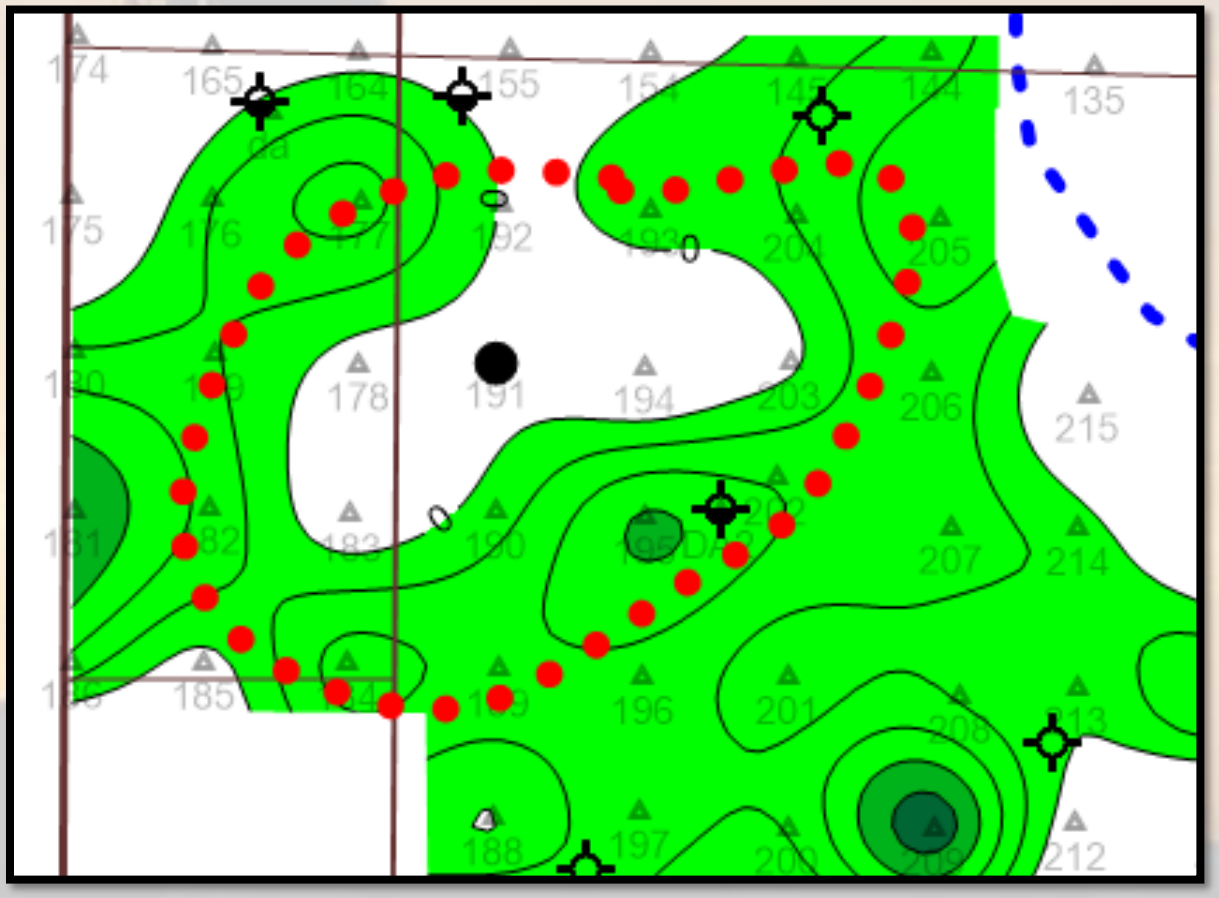


MINEROLOGY OF A MICROSEEP

IODINE

Iodine is a “Halo” indicator with hydrocarbons causing the stable indigenous soil concentration to become volatile resulting in sublimation to the atmosphere. Depletion of iodine is expected in areas of hydrocarbon microseepage.

Iodine is chemically associated with caliche. It is mined in Caliche ore deposits in Chile. High Iodine is indicative of high caliche that is associated with microseepage.
In the subsurface, Iodine increases concentration in reservoir waters near oil/water contacts.



“HALO” ANOMALY
One well field

MINEROLOGY OF A MICROSEEP

TRACE ELEMENTS

Hydrocarbon microseepage is buoyancy driven. Many elements associated with crude oil will piggyback their way to the surface. (Disputed by some experts)

Crude Oil Trace Element Analysis.

Pennsylvanian

Element	ppm
sulfur	7750
copper	28.2
nickel	14.9
zinc	12.6
tungston	11.2
vanadium	7.57

Permian

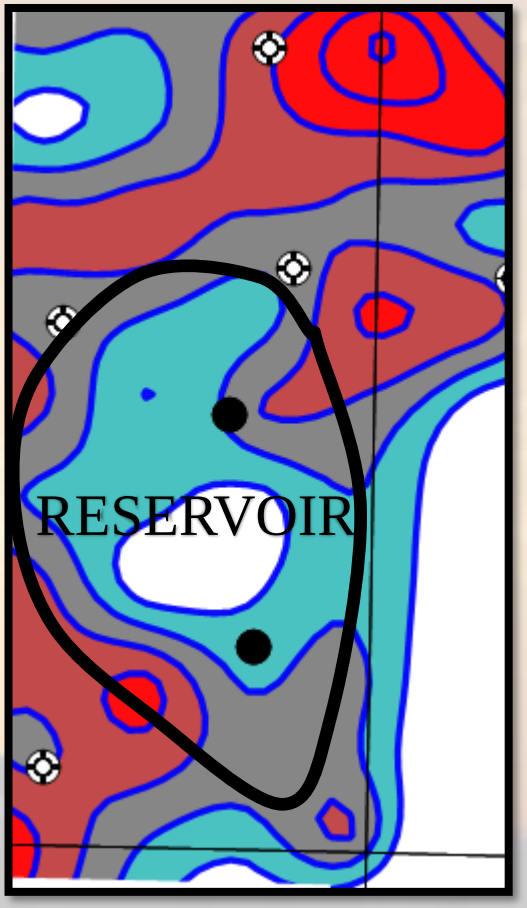
Element	ppm
sulfur	30000
vanadium	36.8
nickel	35.7
copper	11.6
tungsten	6.7
zinc	6.48

HALO RESERVOIR PATTERN

SUM:

Vanadium + Nickel + Copper

HIGH CALICHE IN CENTER OF HALO



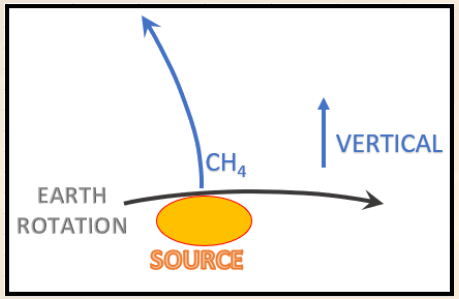
INTERPRETATION IS THE KEY

NEAR VERTICAL MIGRATION

Pressure differential and buoyancy drive hydrocarbons to the surface. Migration travels at approximately 1 inch per year. When reservoir pressure decreases, so does migration. Don't use depleted fields as models.

CORIOLIS EFFECT

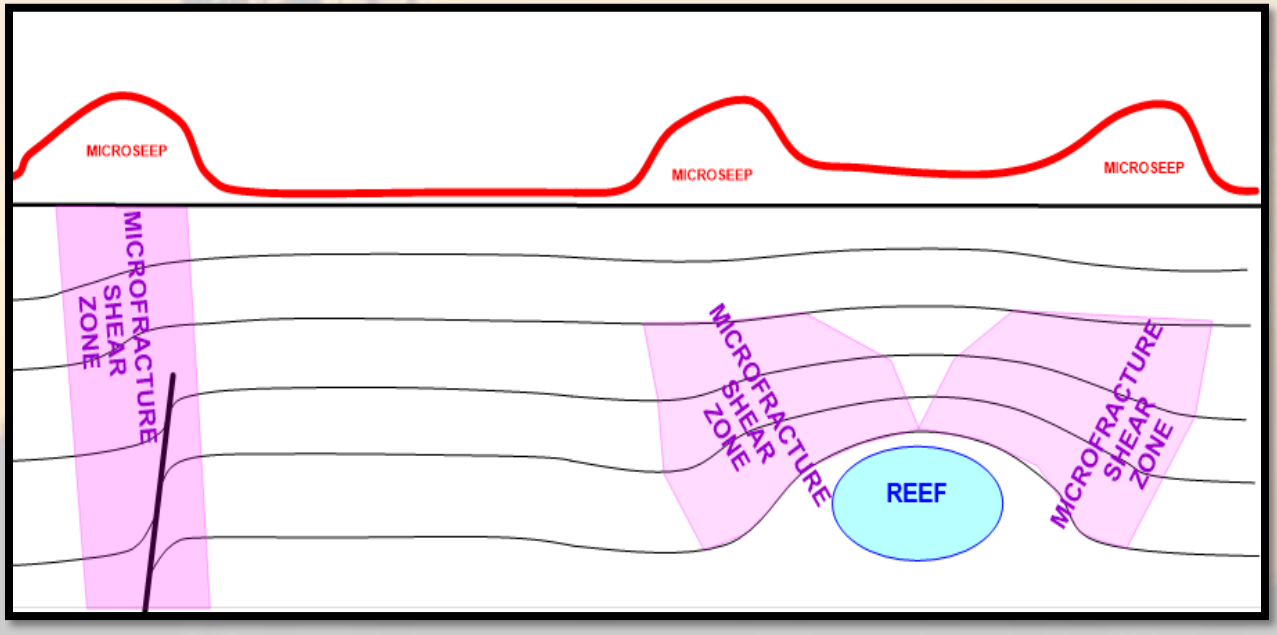
Coriolis has 2 geometry effects. The swirl pattern contributes to "Halo" geometries and a slight westward shift will also be noticed



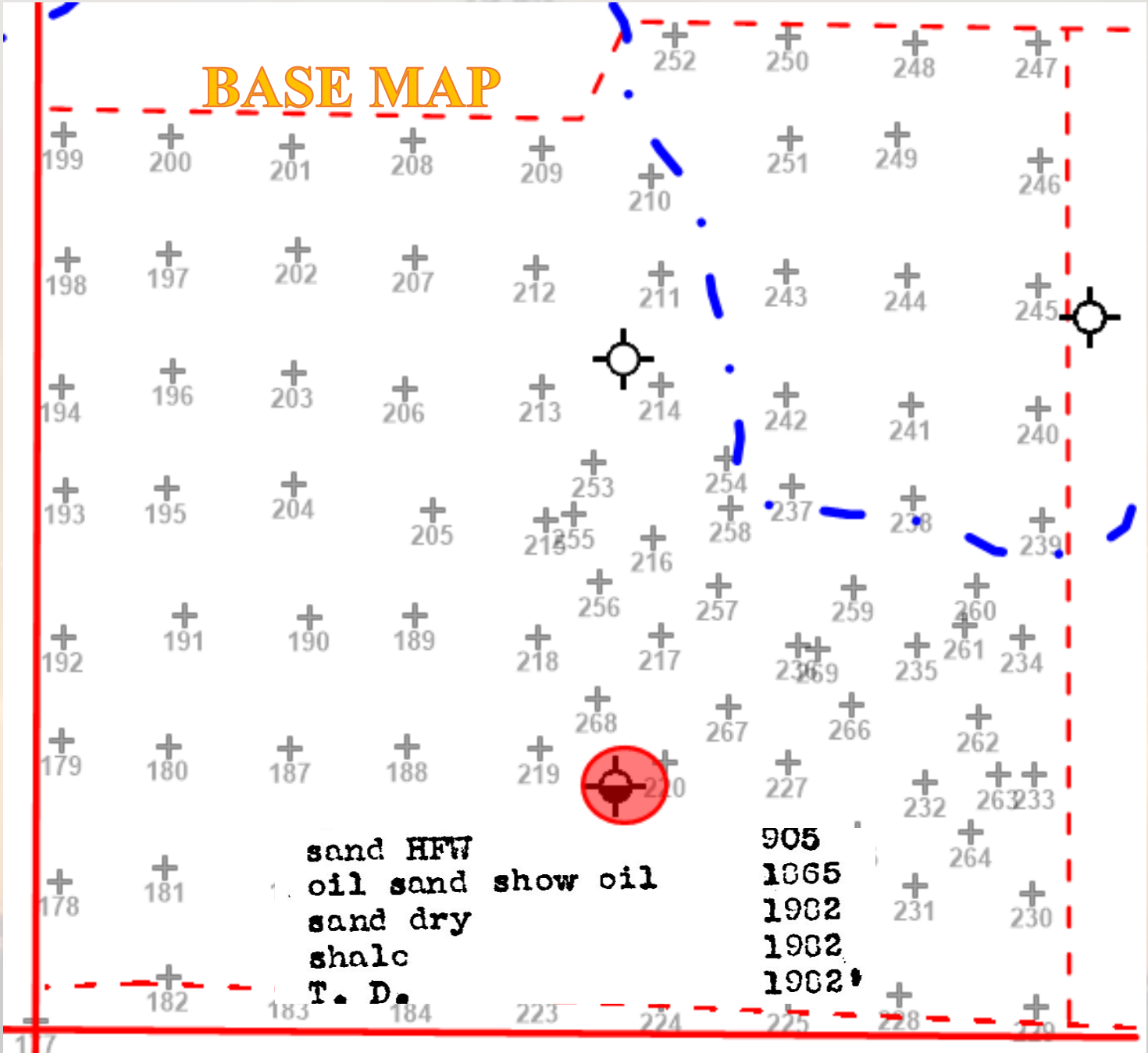
A MICROSEEP MAY NOT BE OVER THE RESERVOIR,

BUT IT WILL BE OVERLAPPING OR OFFSETTING THE RESERVOIR

FRACTURES & MICROFRACTURES DOMINATE MIGRATION



District 7B – APICAL – 1800 ft.



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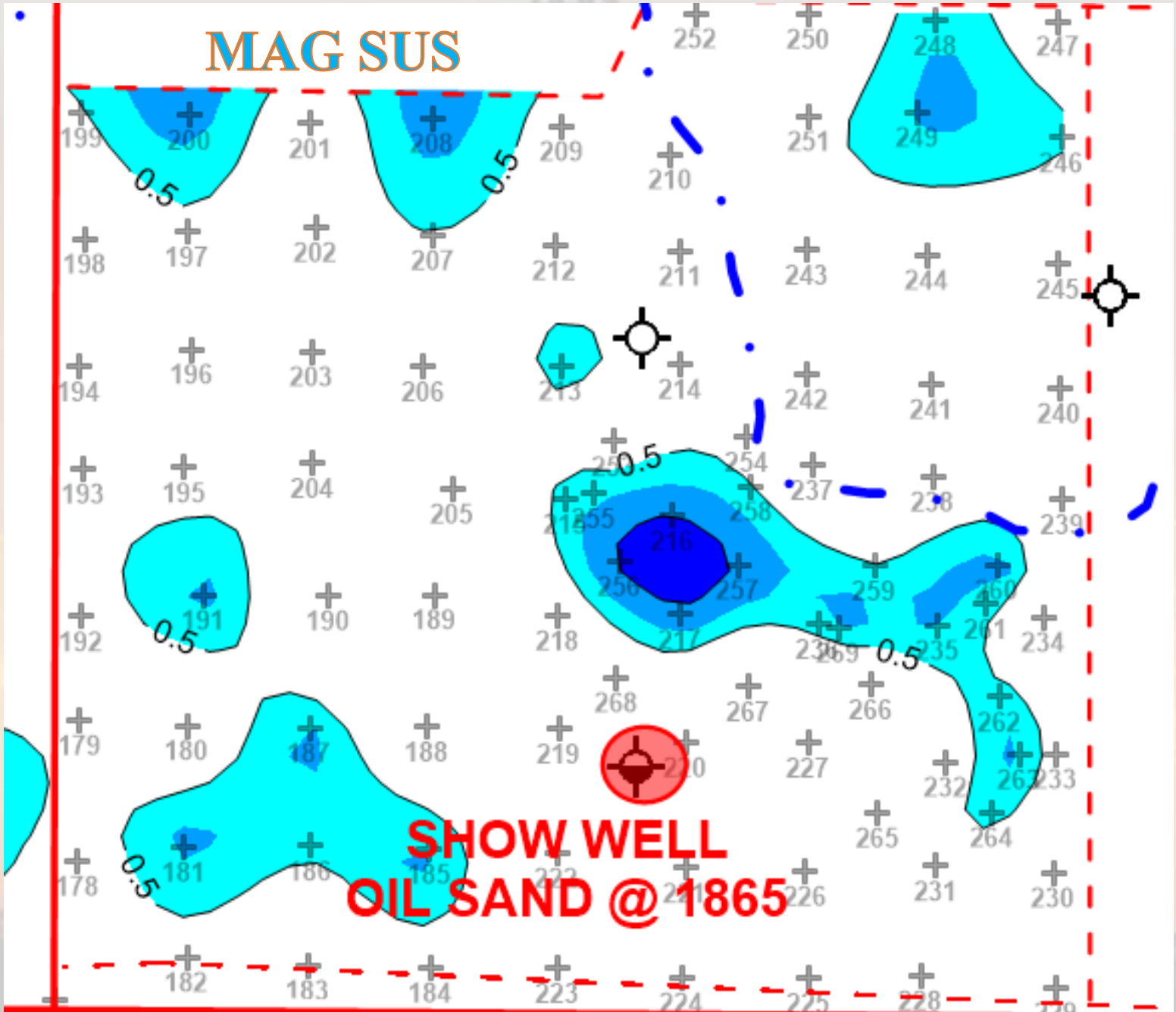

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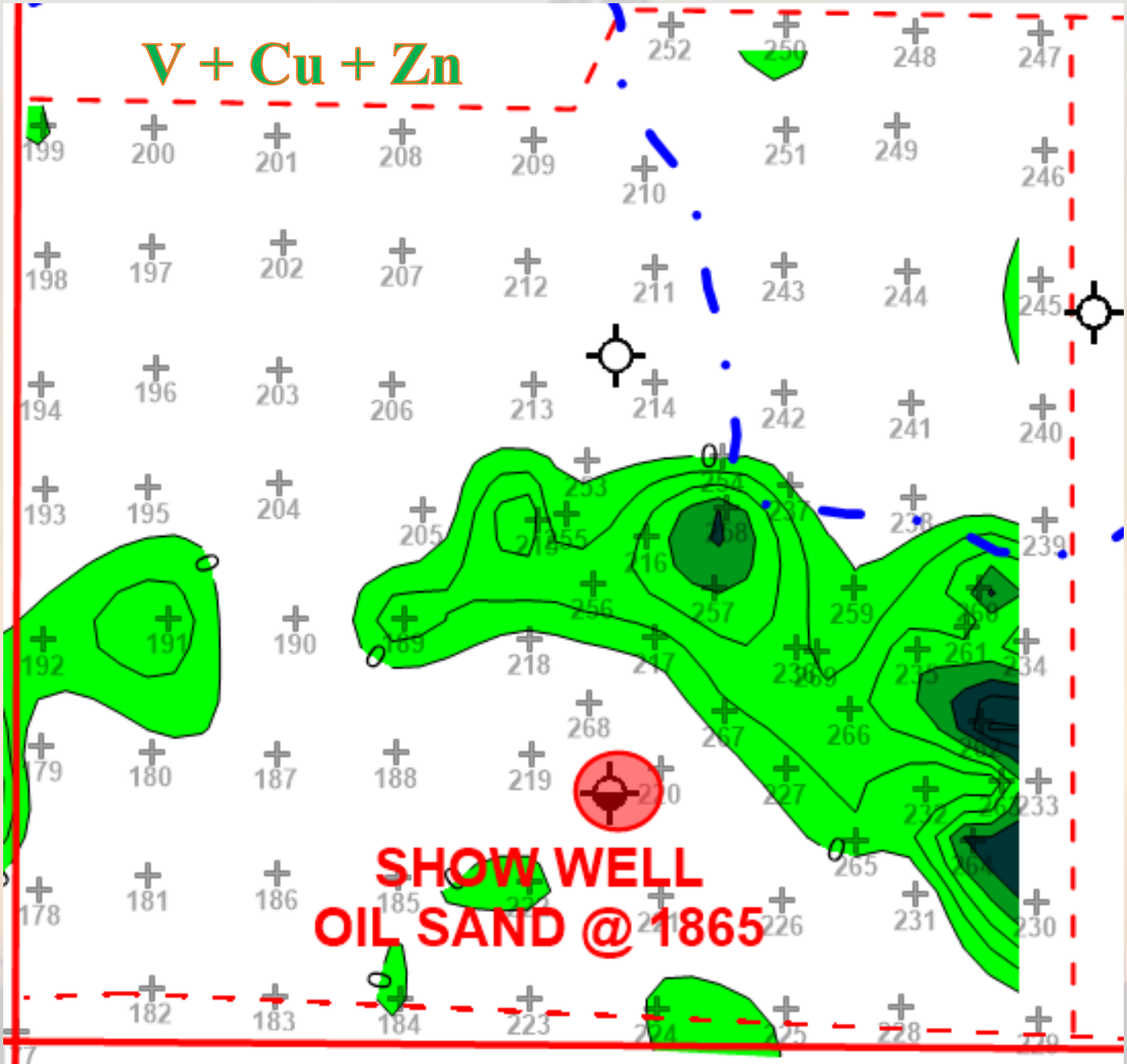

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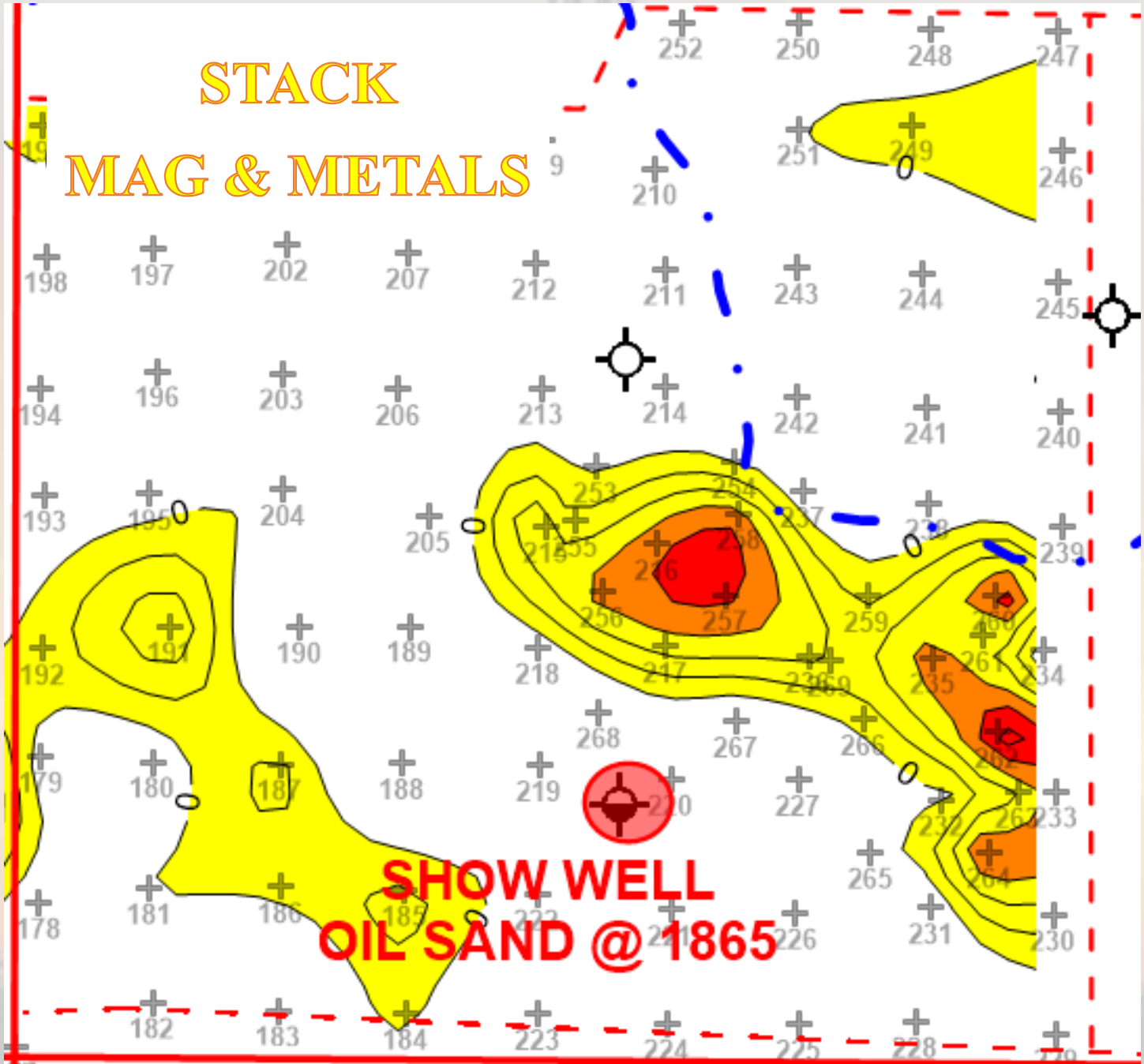

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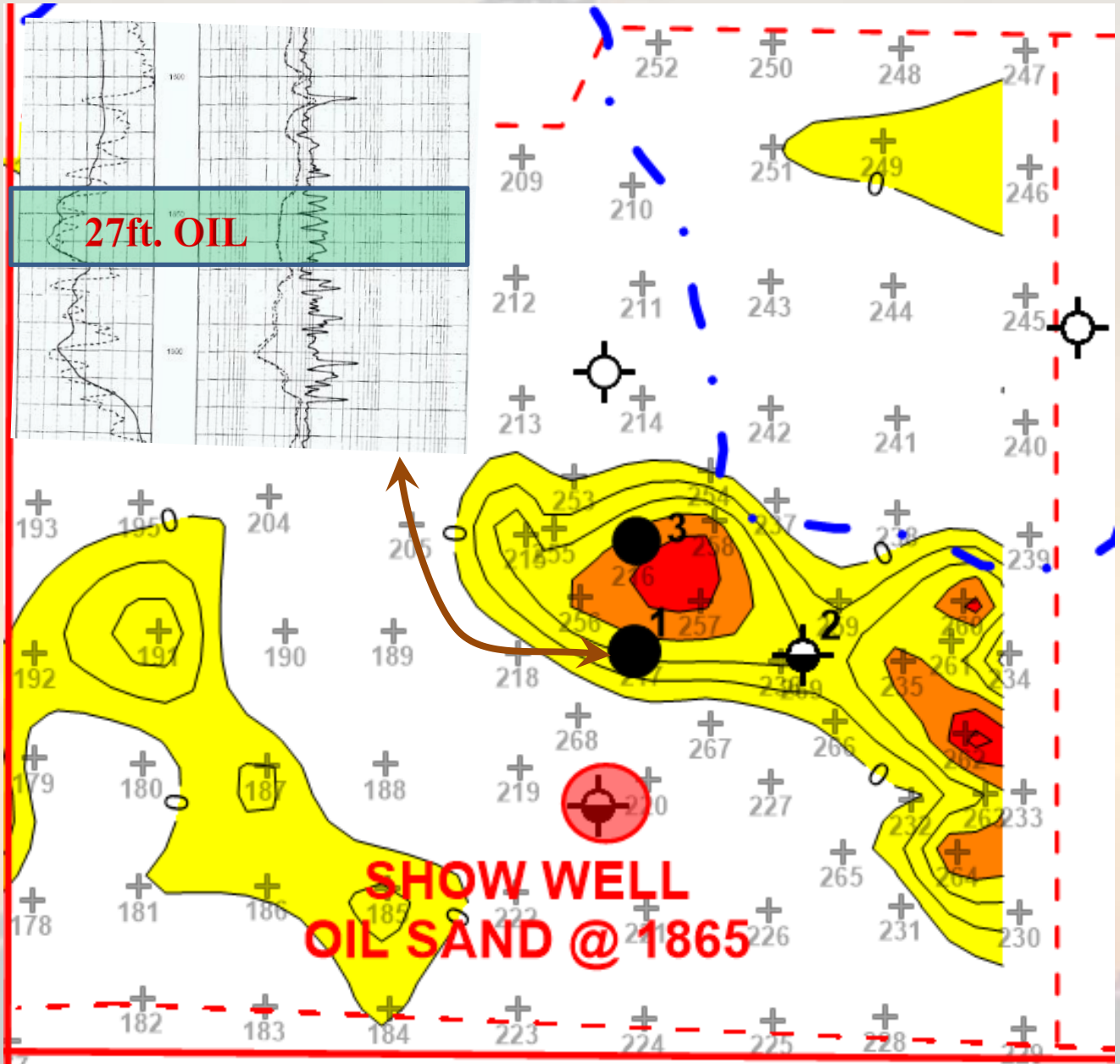
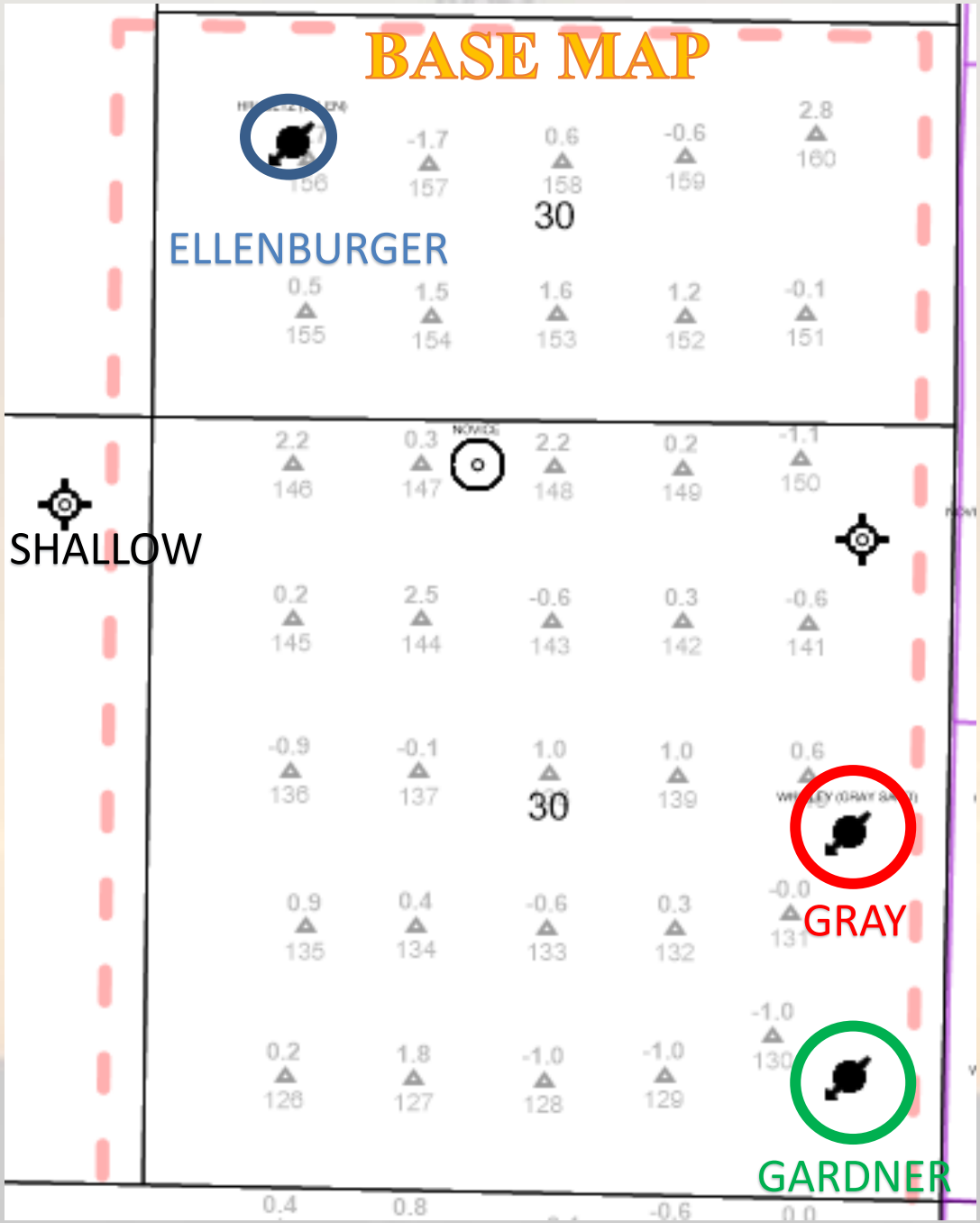
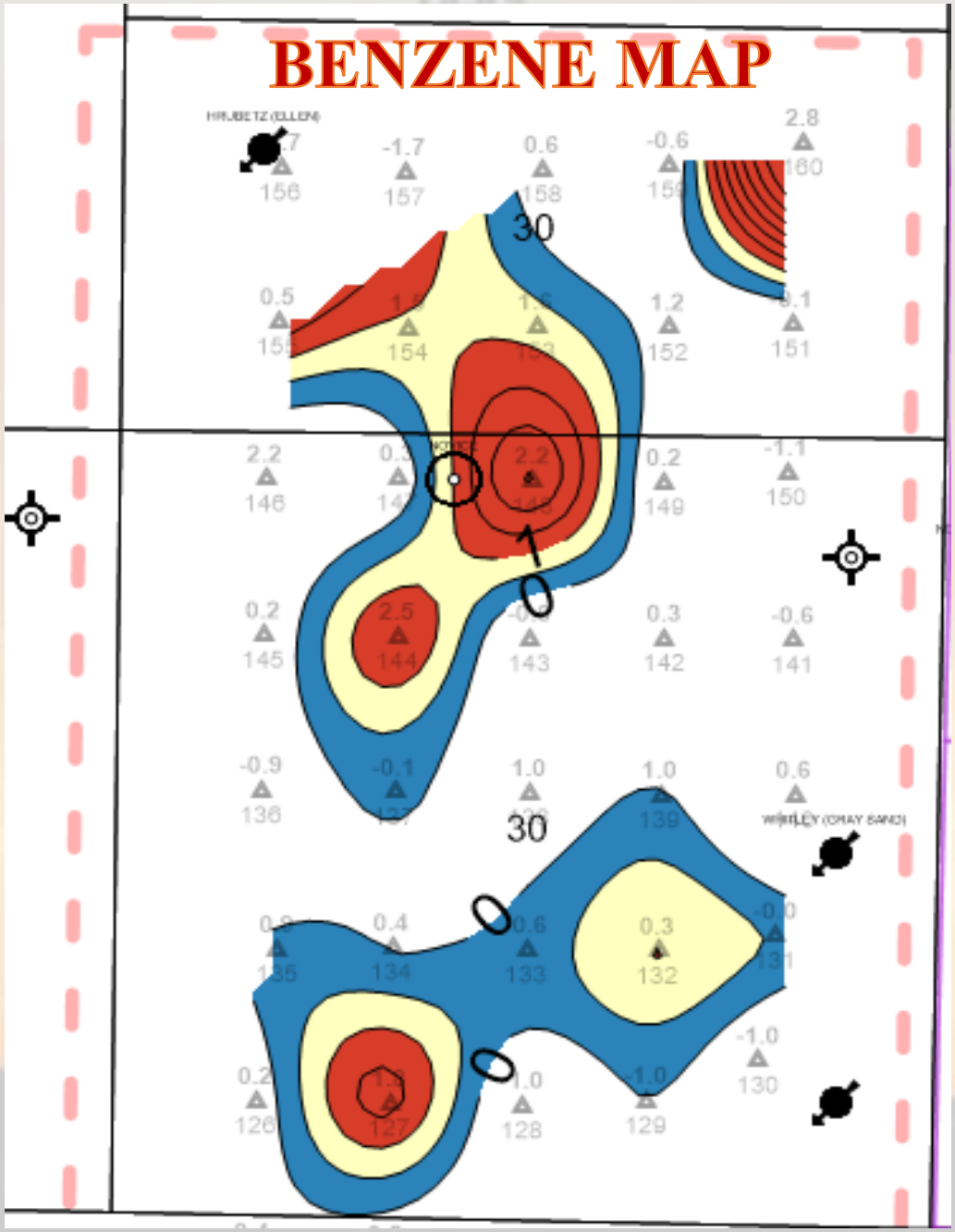


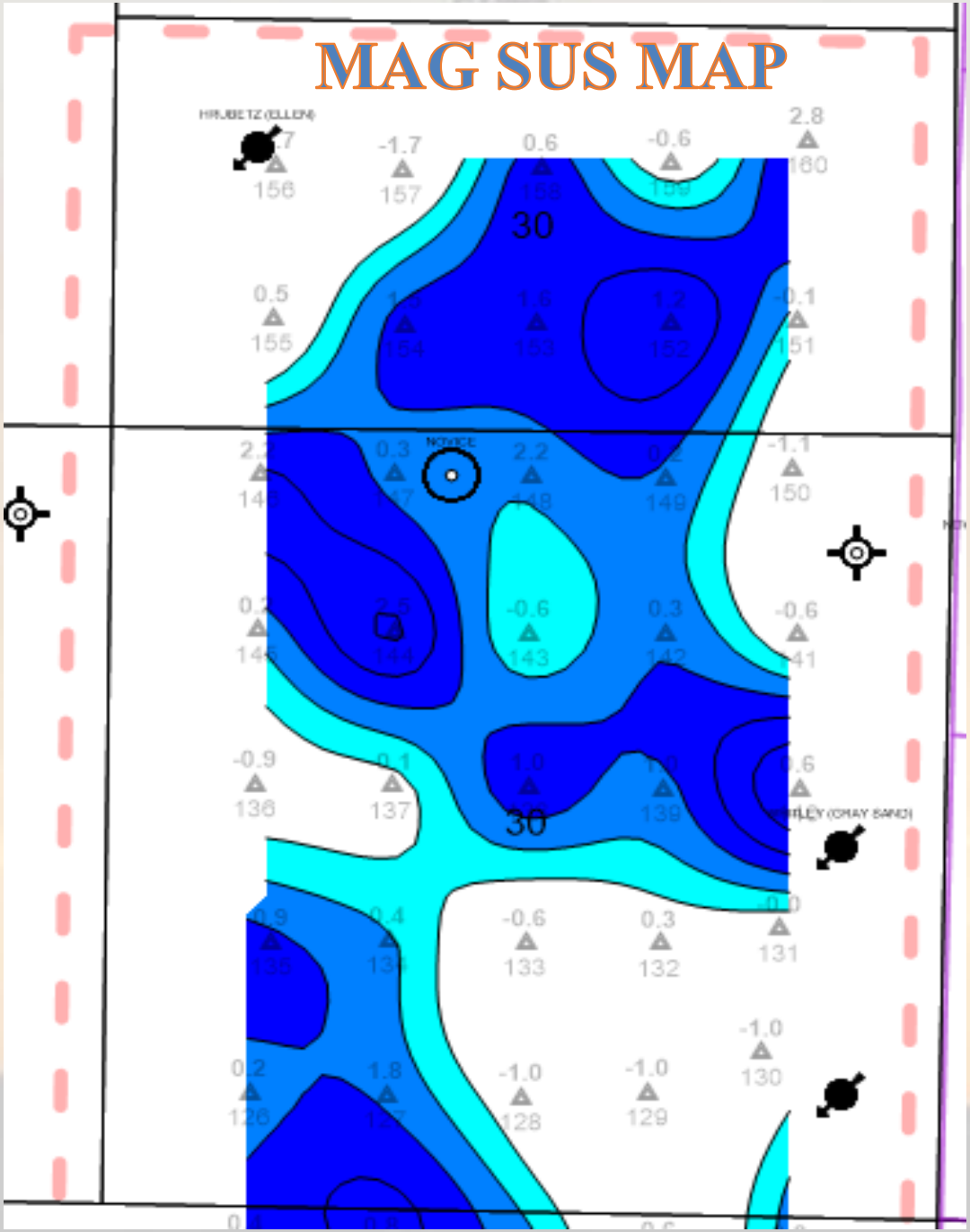
District 7B – APICAL – 3100 ft. - 4600 ft.



District 7B – APICAL – 3100 ft. - 4600 ft.



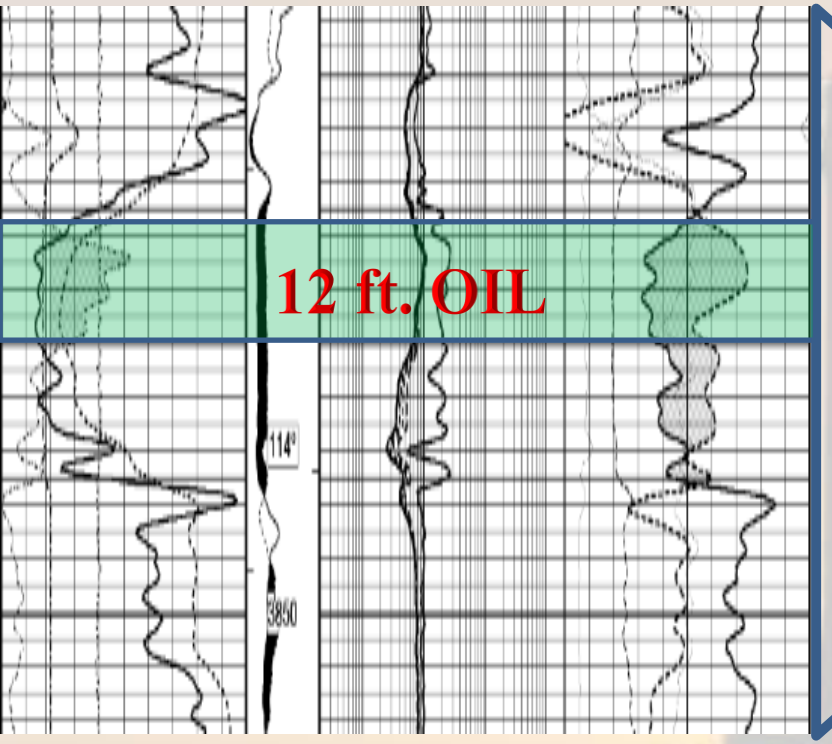
District 7B – APICAL – 3100 ft. - 4600 ft.

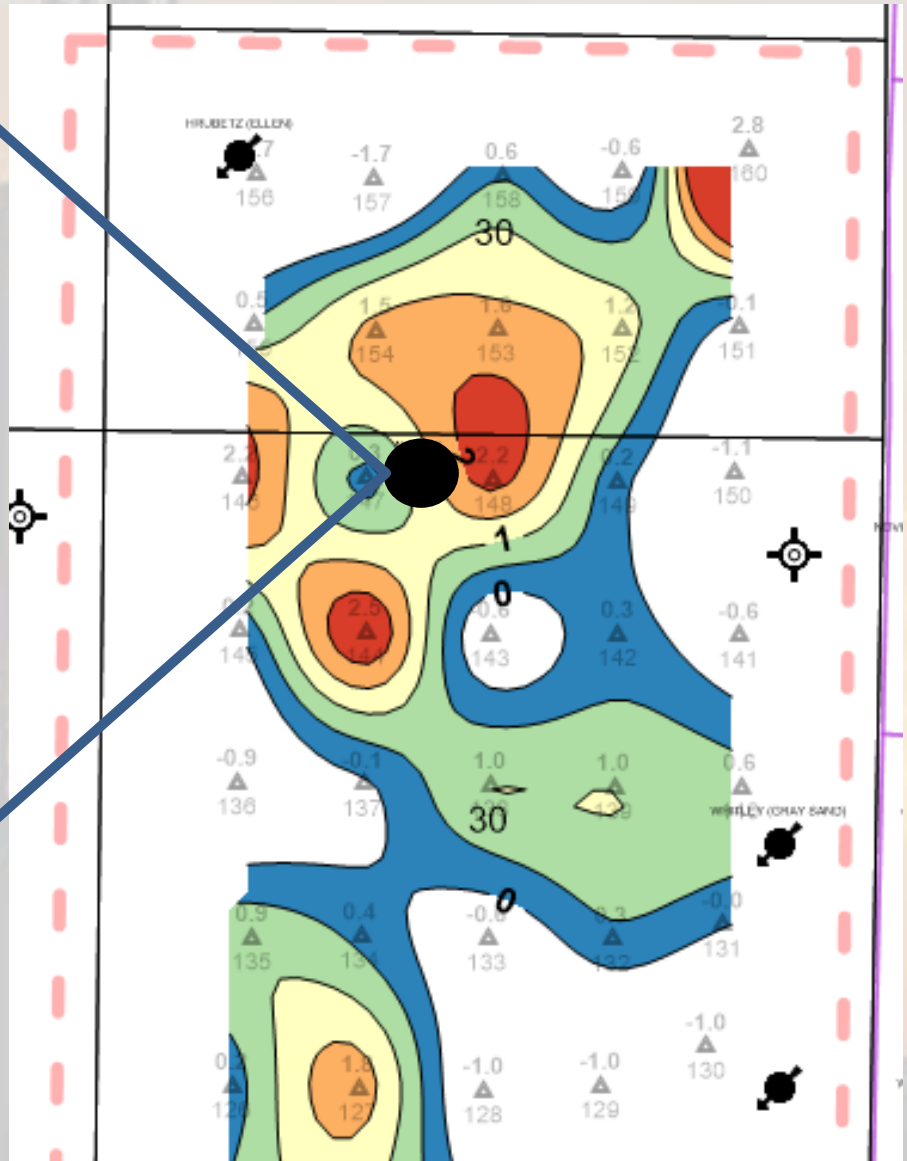


District 7B – SIMI-APICAL – 3100 ft. - 4600 ft.

STACK

BENZENE & MAG SUS MAP





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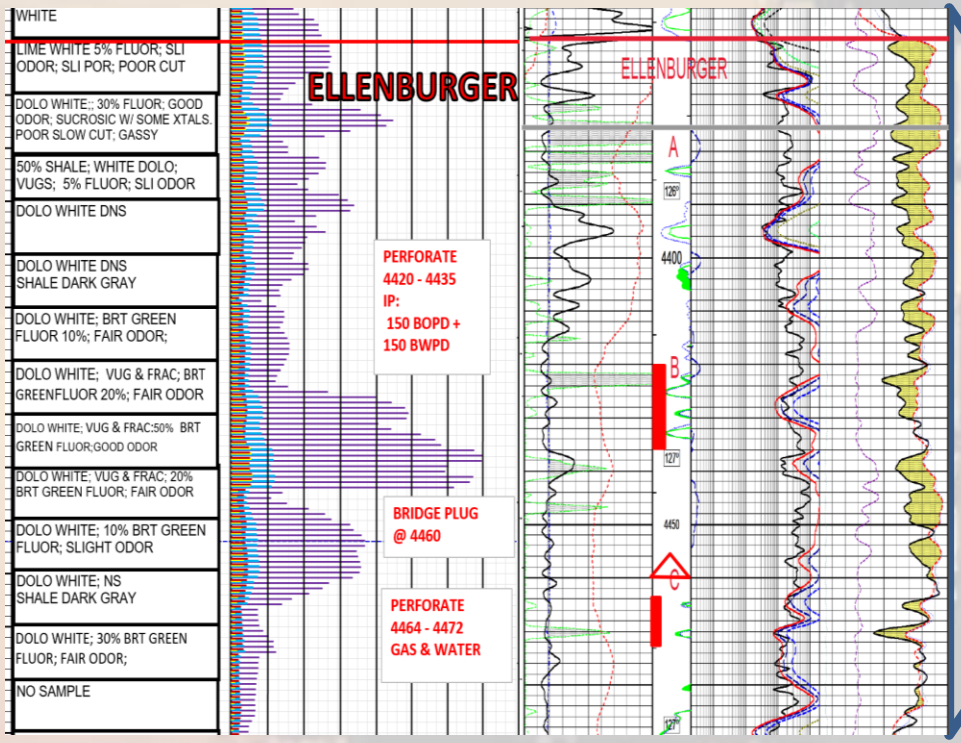
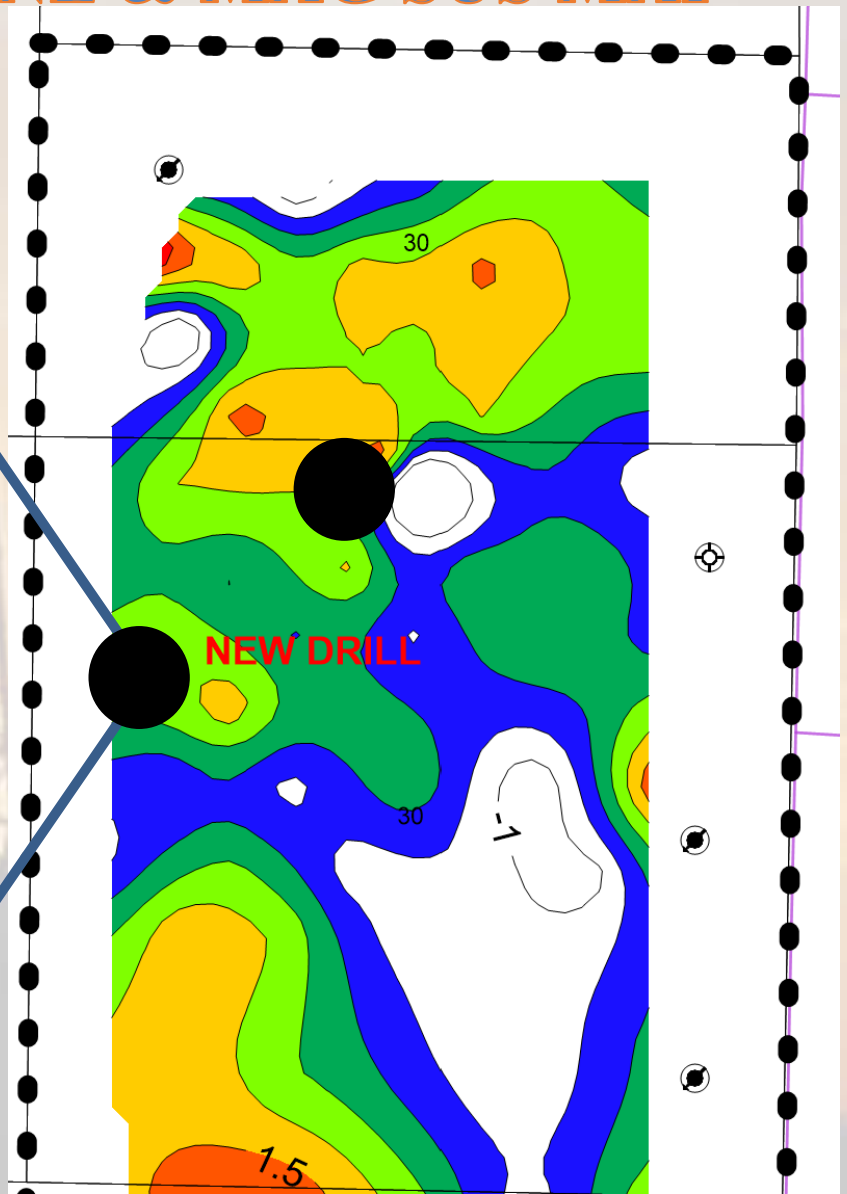
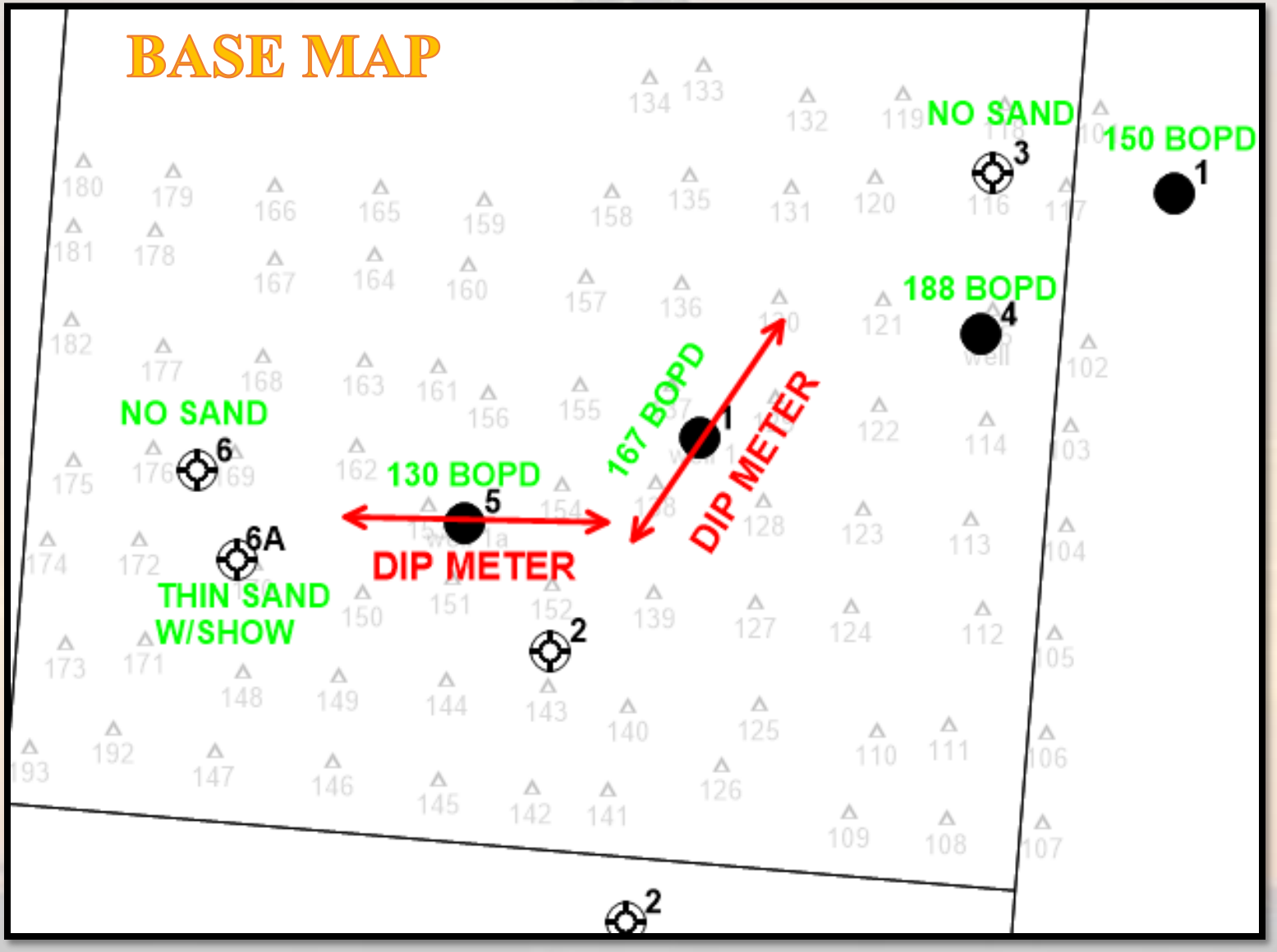




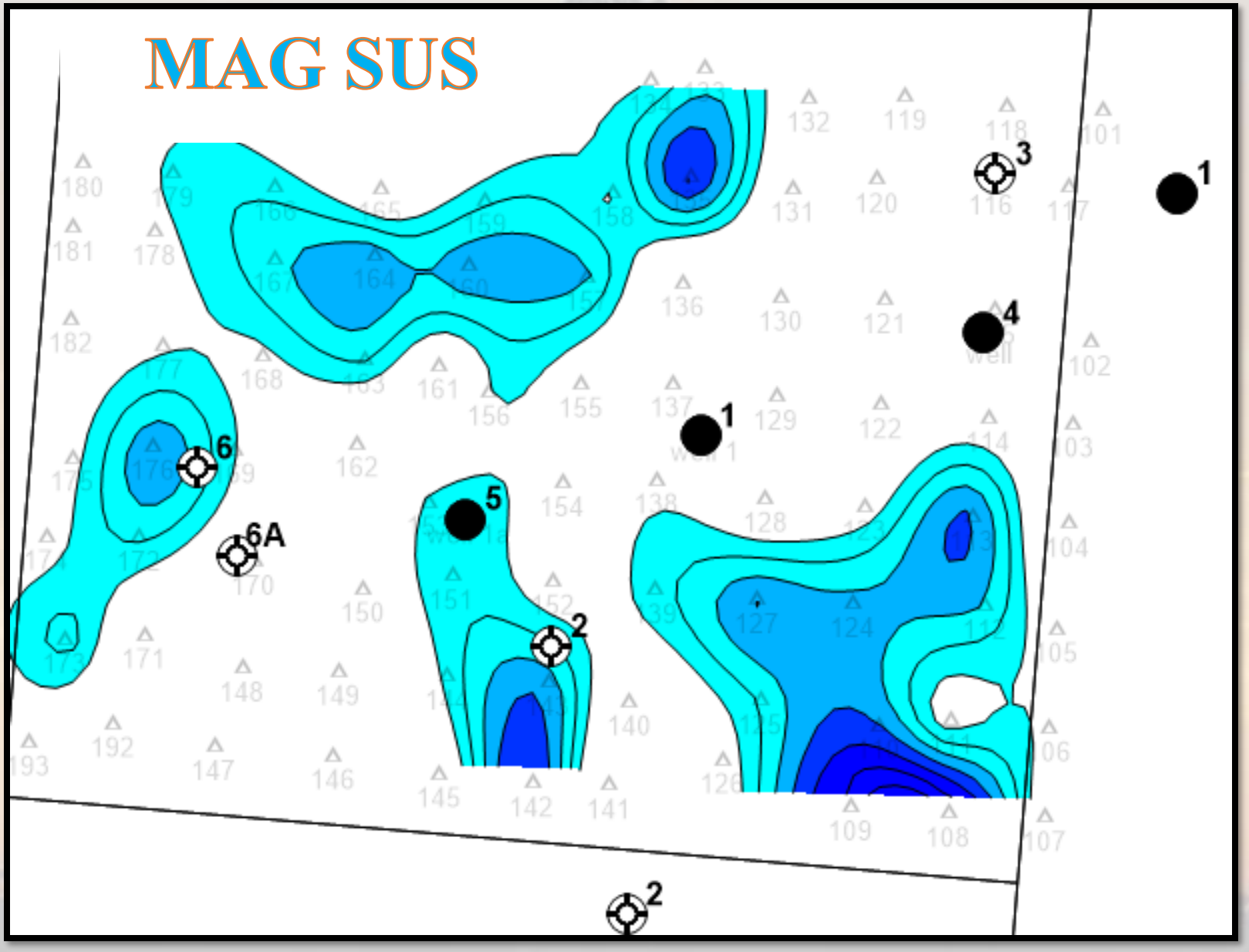
District 8A

Halo example; 5500 feet



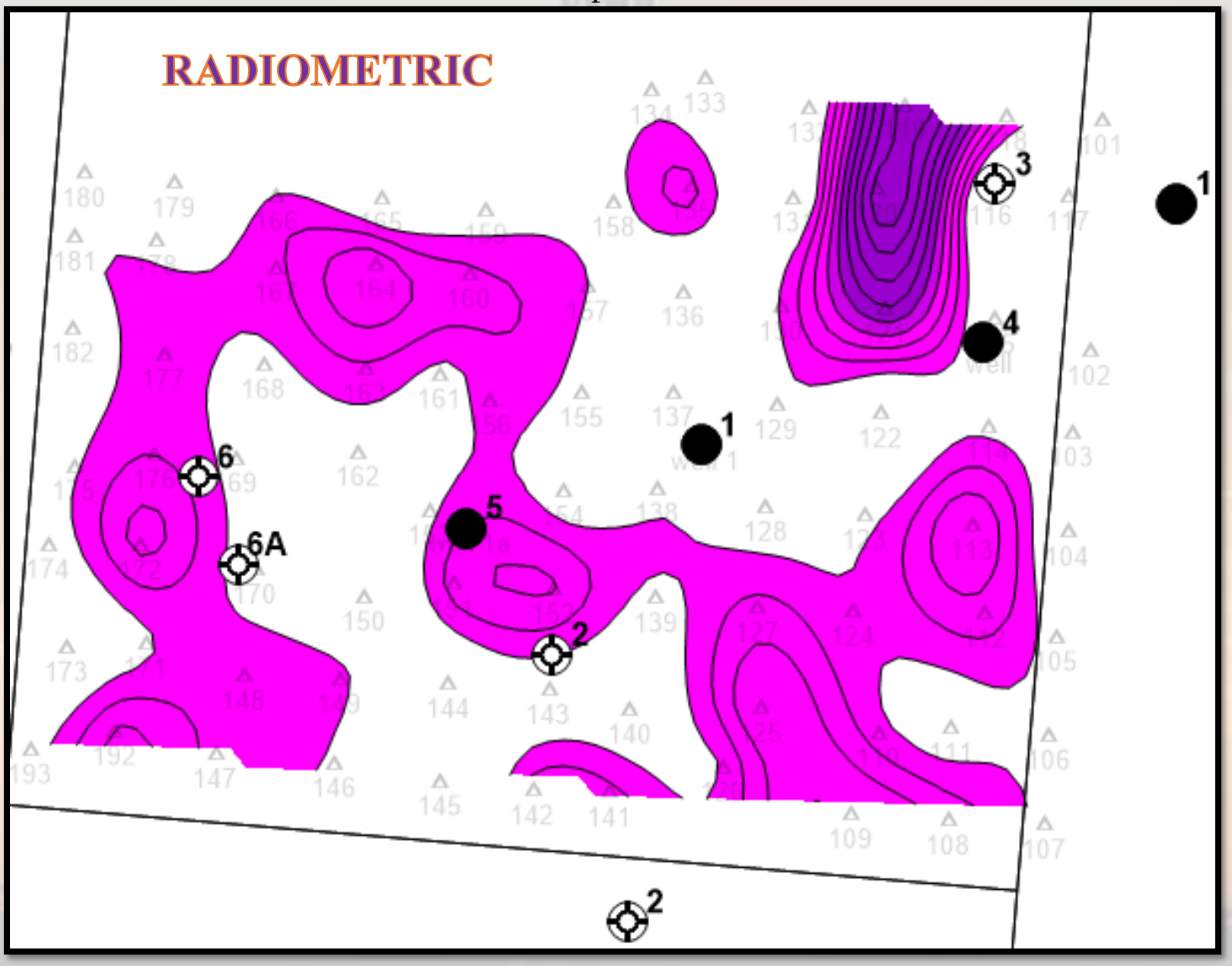
District 8A

Halo example; 5500 feet



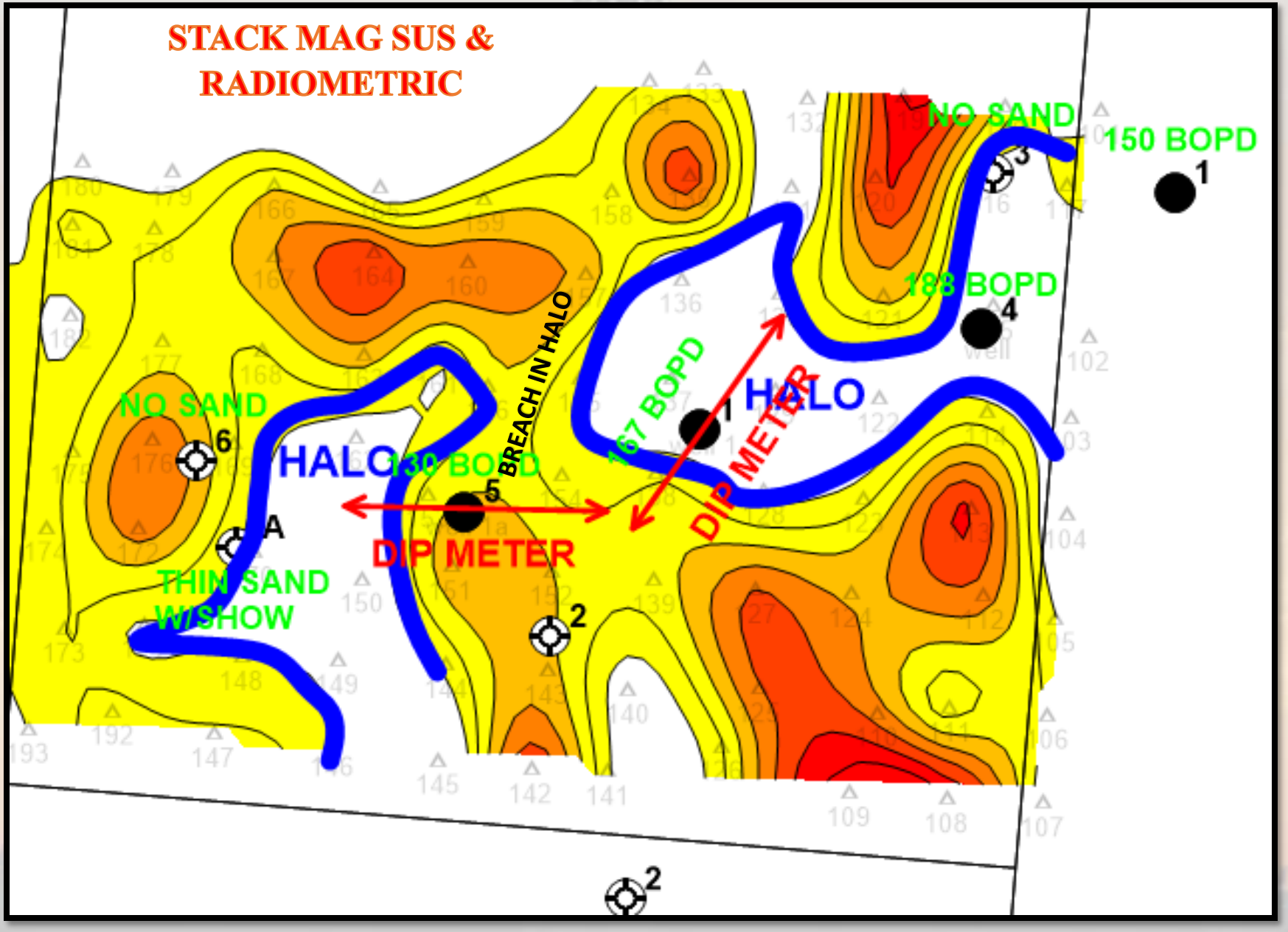
District 8A

Halo example; 5500 feet

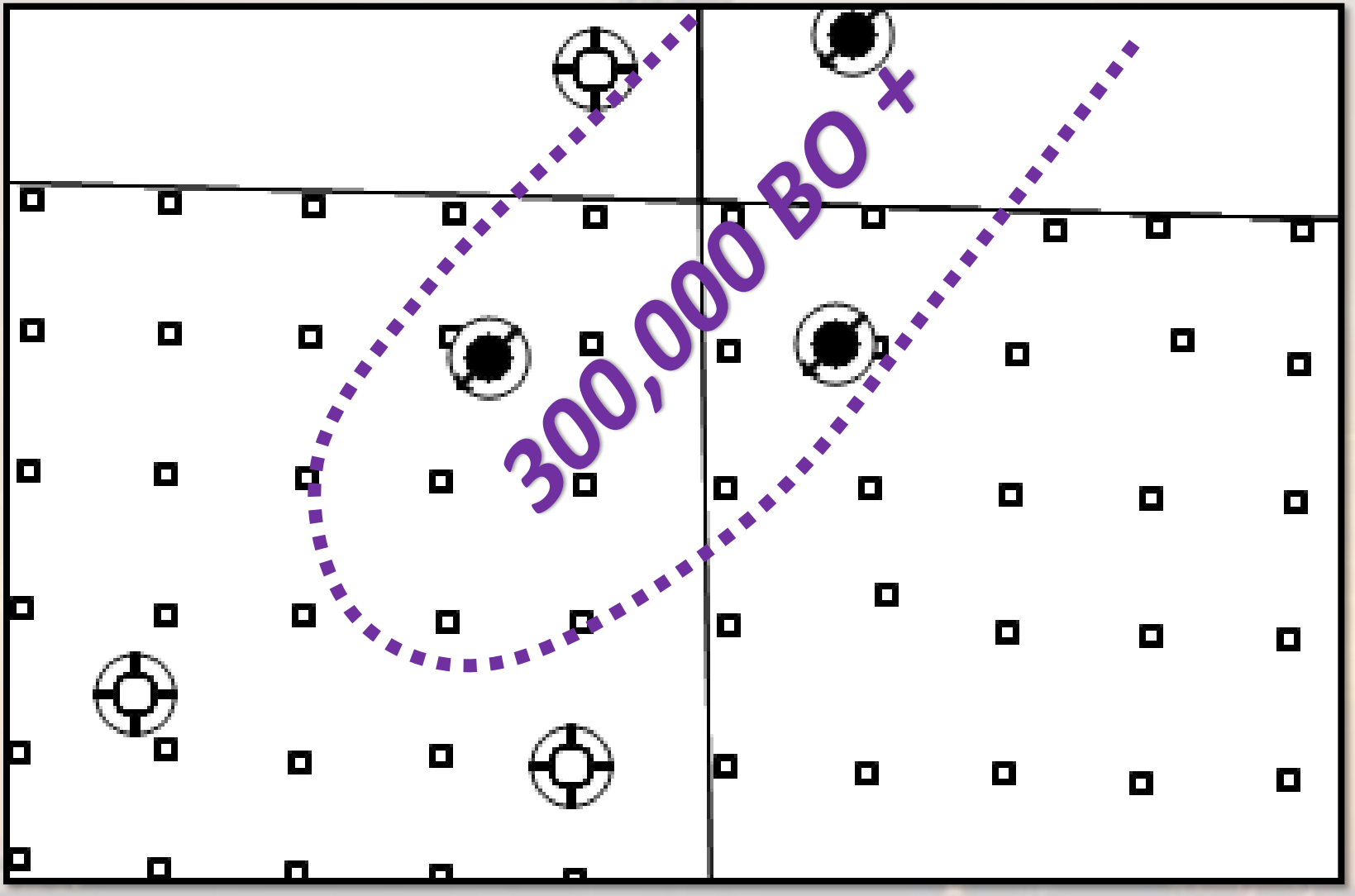


District 8A

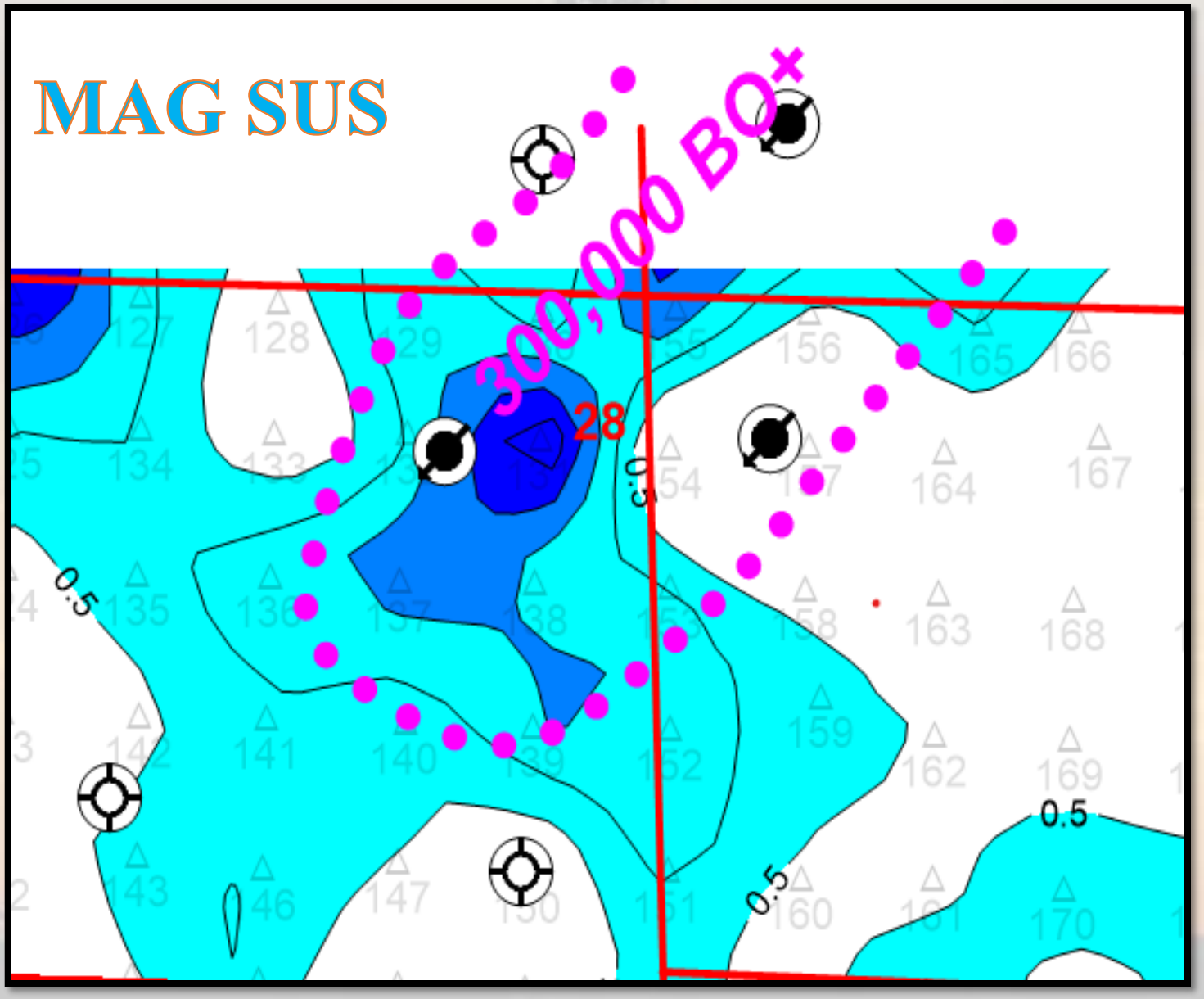
Halo example; 5500 feet



District 9
Apical example 6300 feet



District 9
Apical example 6300 feet



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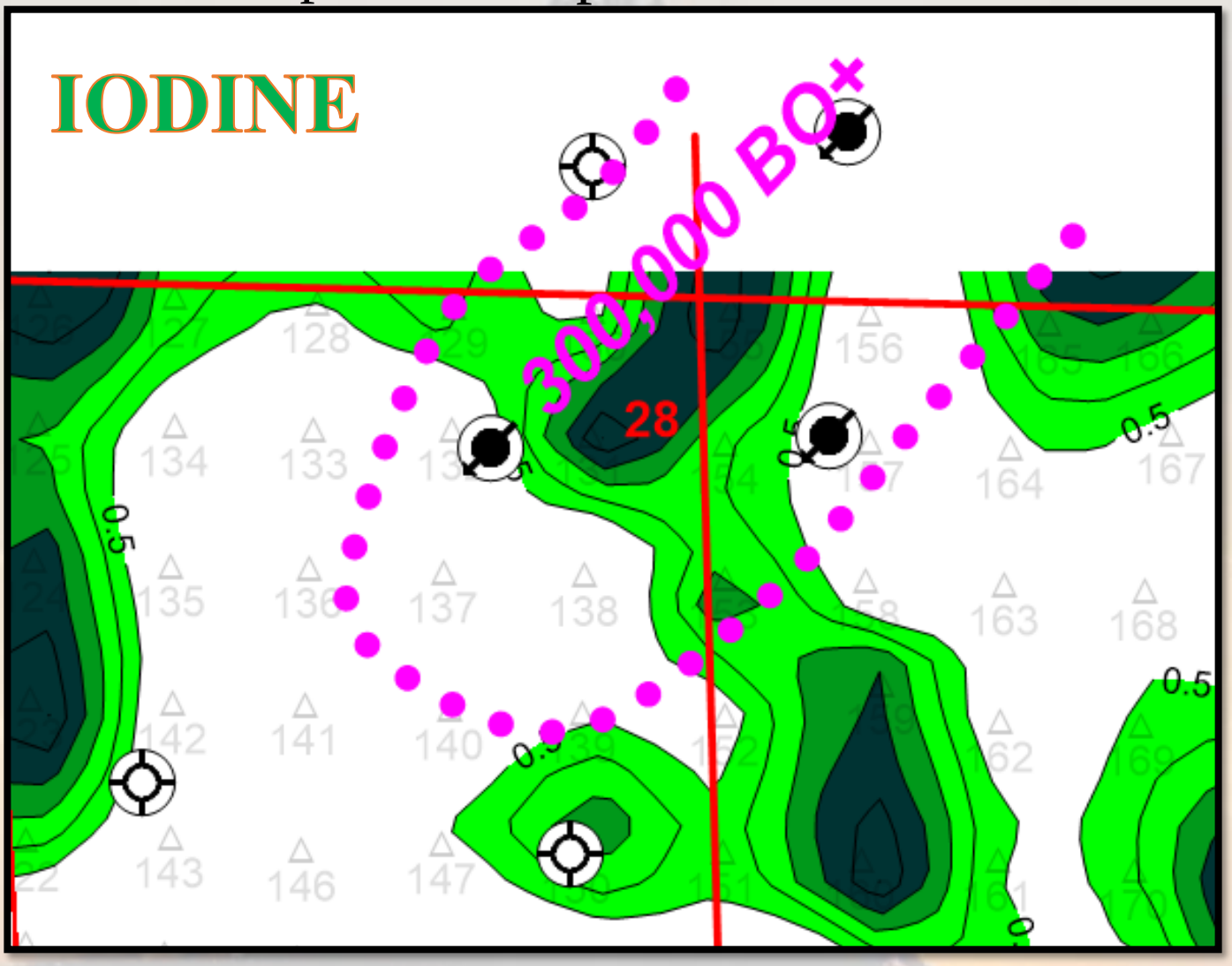
Apical example 6300 feet



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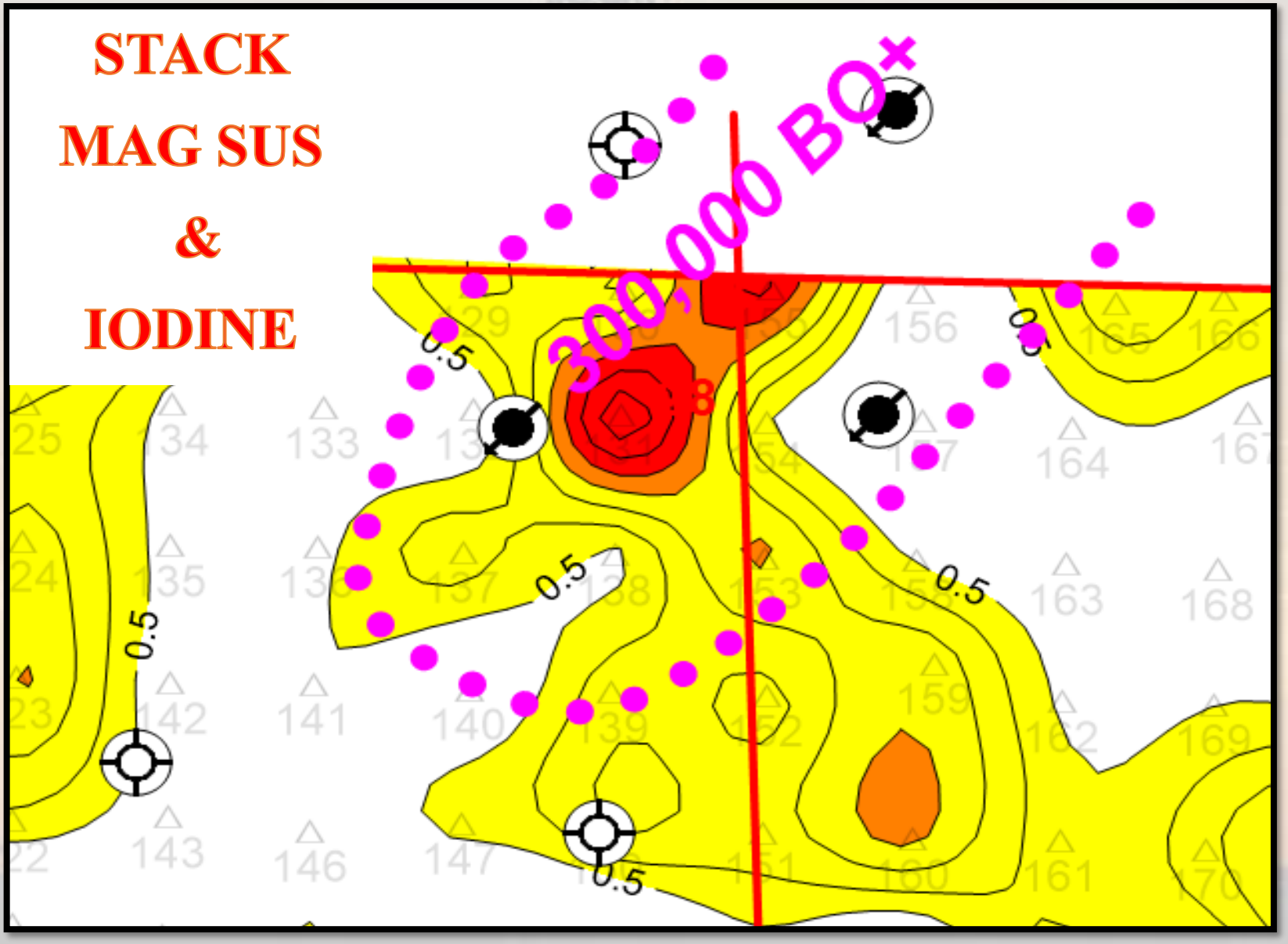
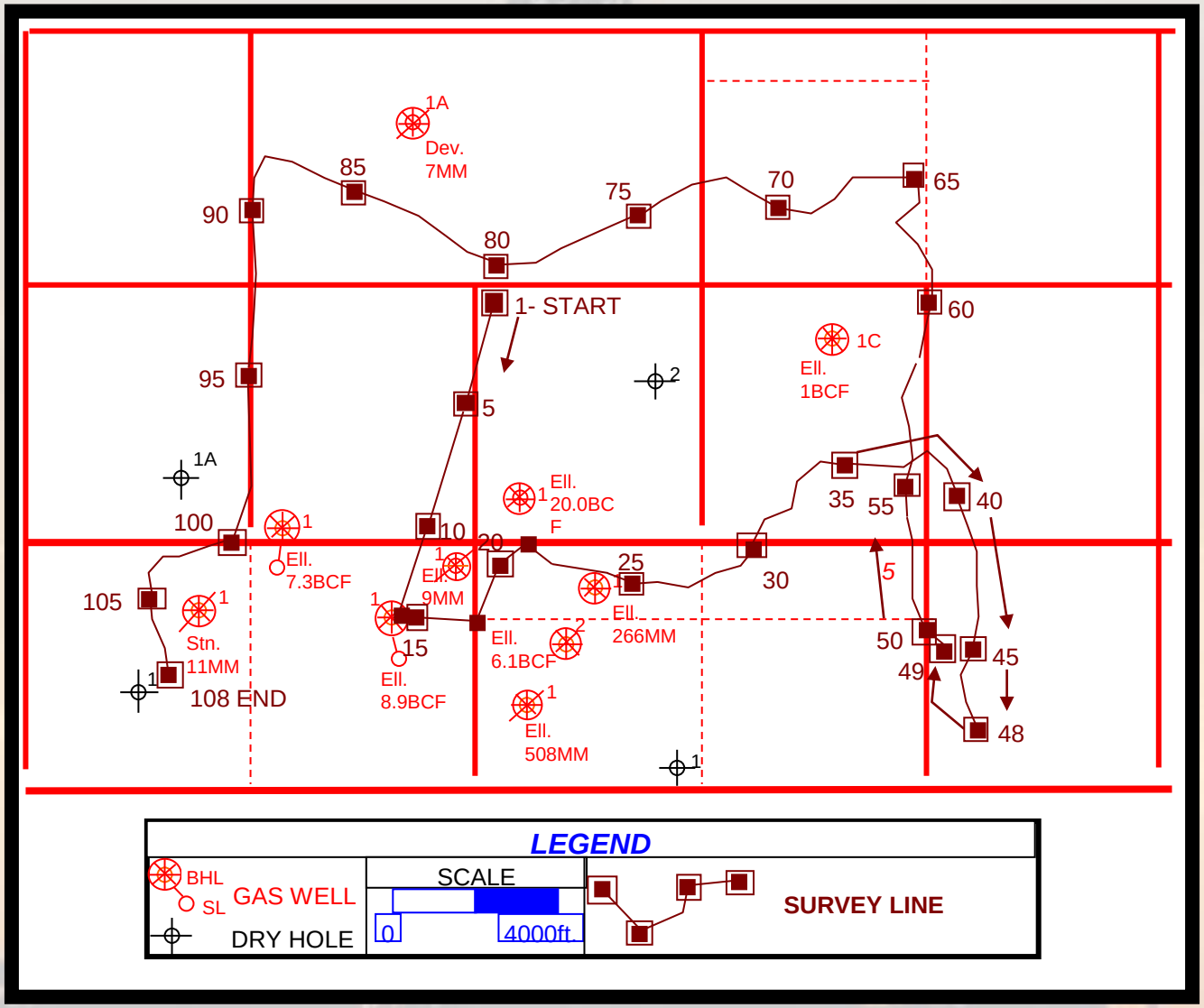
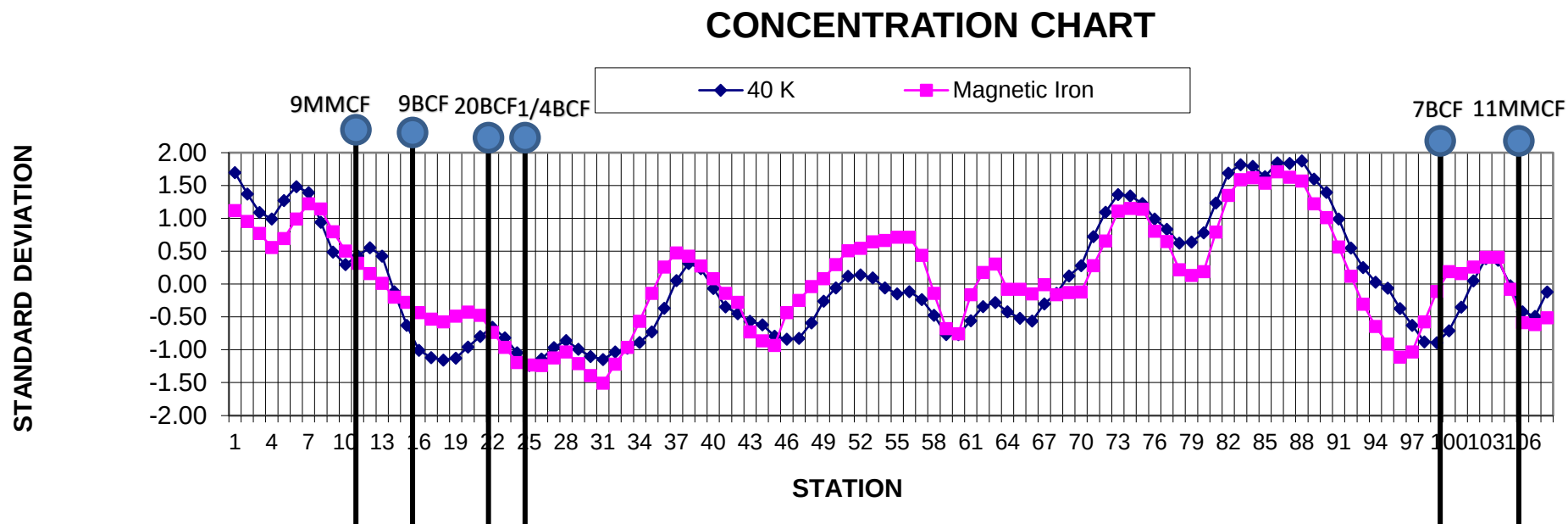
Apical example 6300 feet

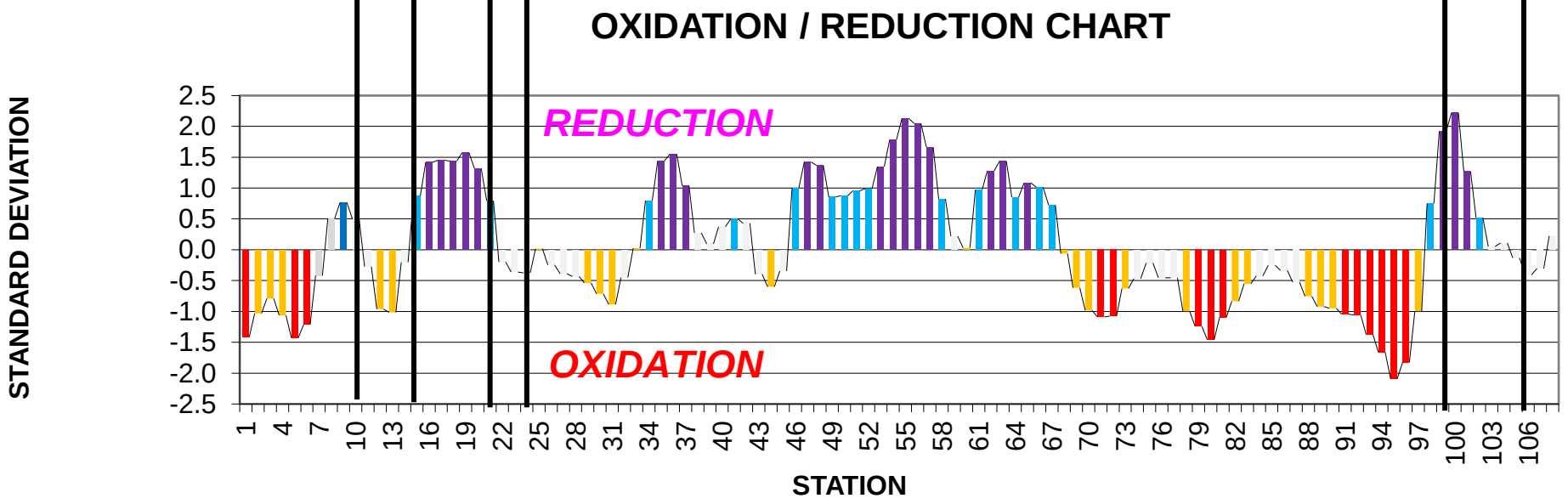


12,000 FEET
MILLER ELLENBURGER FIELD

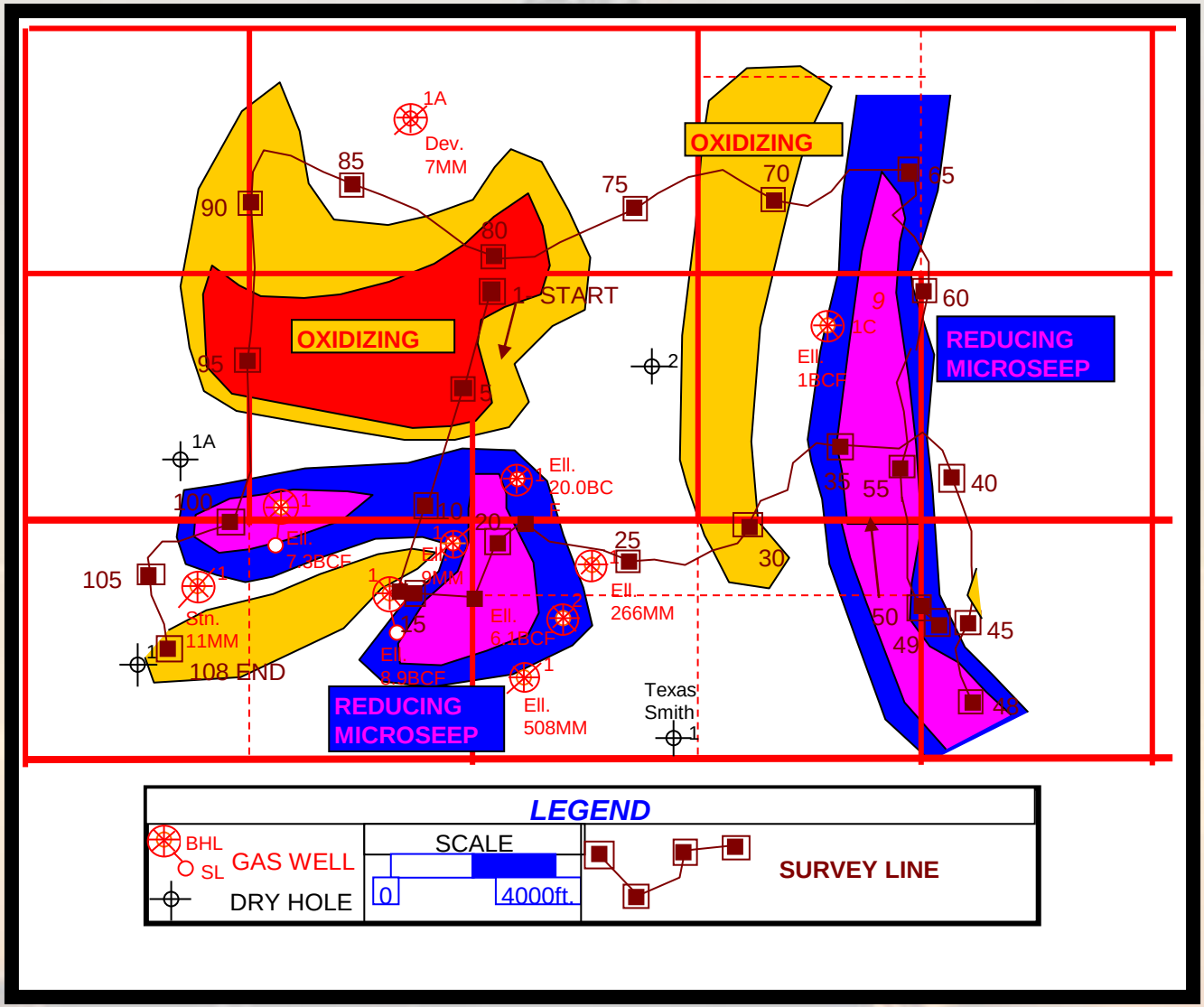


12,000 FEET ELLENBURGER

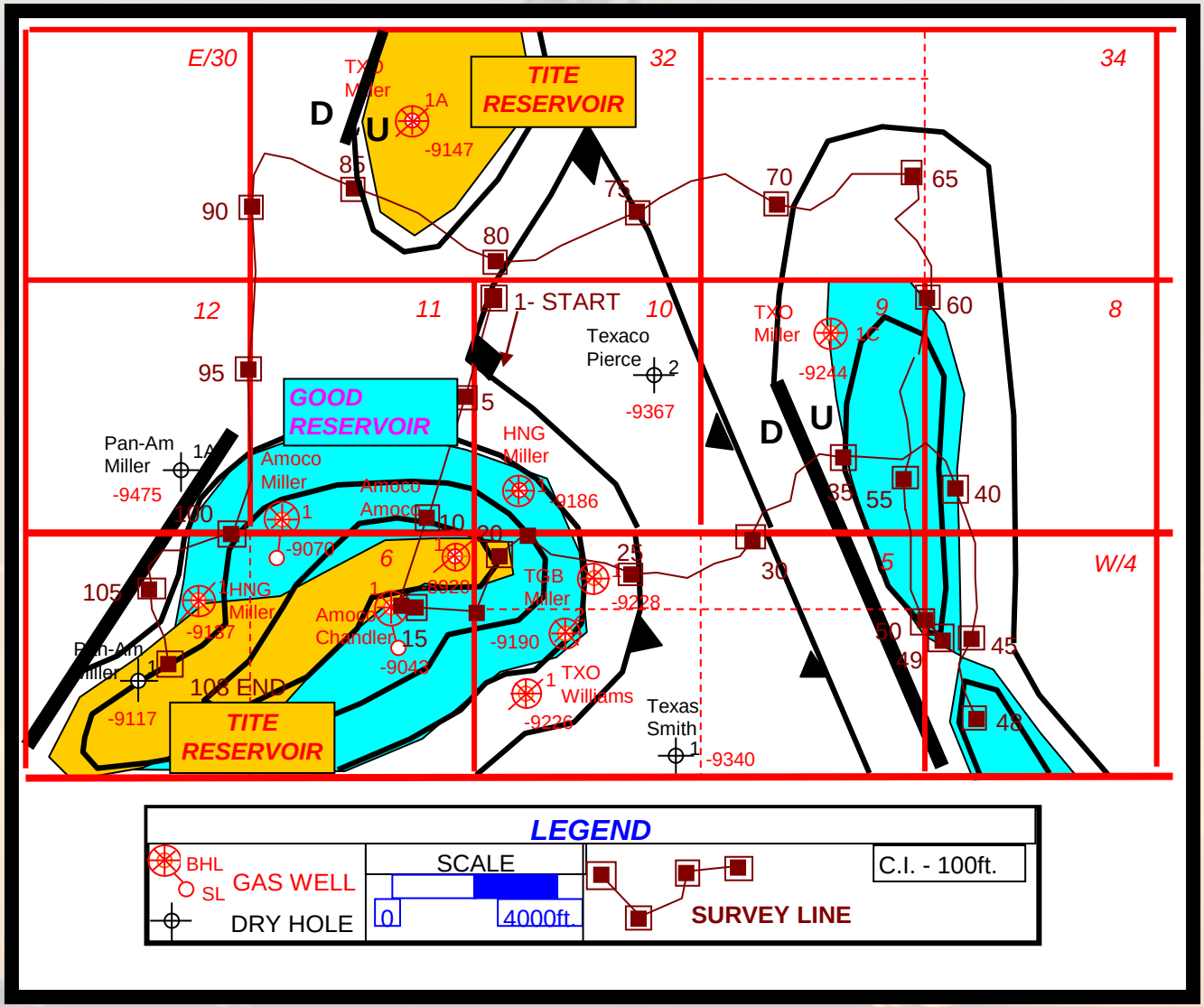




12,000 FEET ELLENBURGER



12,000 FEET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Amoco
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Amoco
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Miller
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TITE
RESERVOIR
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Texas
Smith
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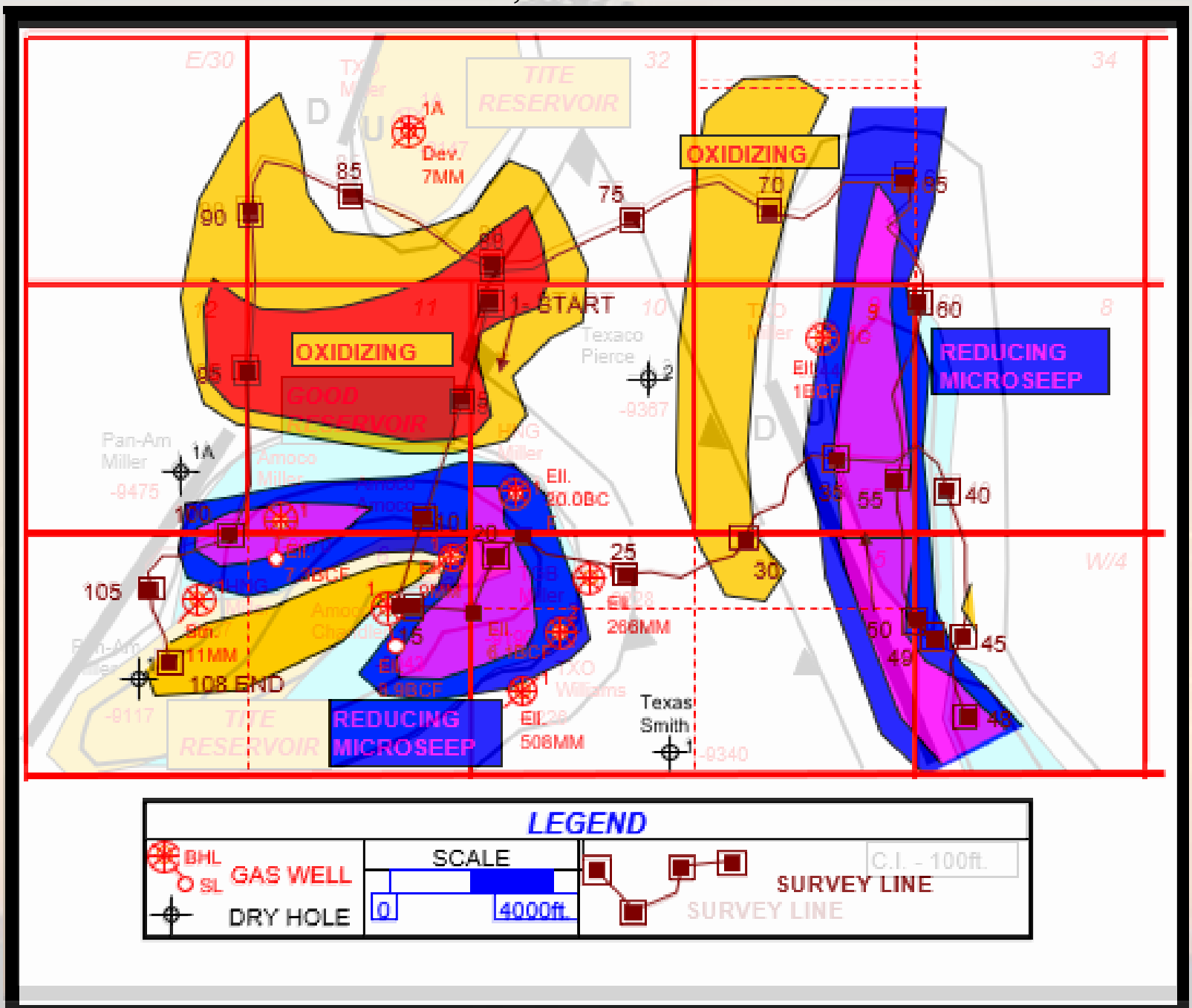
4000ft.
C.I. - 100ft.
SURVEY LINE

12,000 FEET


OXIDIZING
GOOD RESERVOIR
OXIDIZING
REDUCING MICROSEEP
REDUCING MICROSEEP
TITE RESERVOIR
TITE RESERVOIR
1- START
108 END
Dev. 7MM
Ell. 20.0BC
Ell. 7.3BCF
Ell. 286MM
Ell. 6.4BCF
Ell. 3.9BCF
Ell. 508MM
Ell. 1BCF
Texaco Pierce
Pan-Am Miller
Amoco Mill
Amoco Chandler
Texas Smith
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GAS WELL
DRY HOLE
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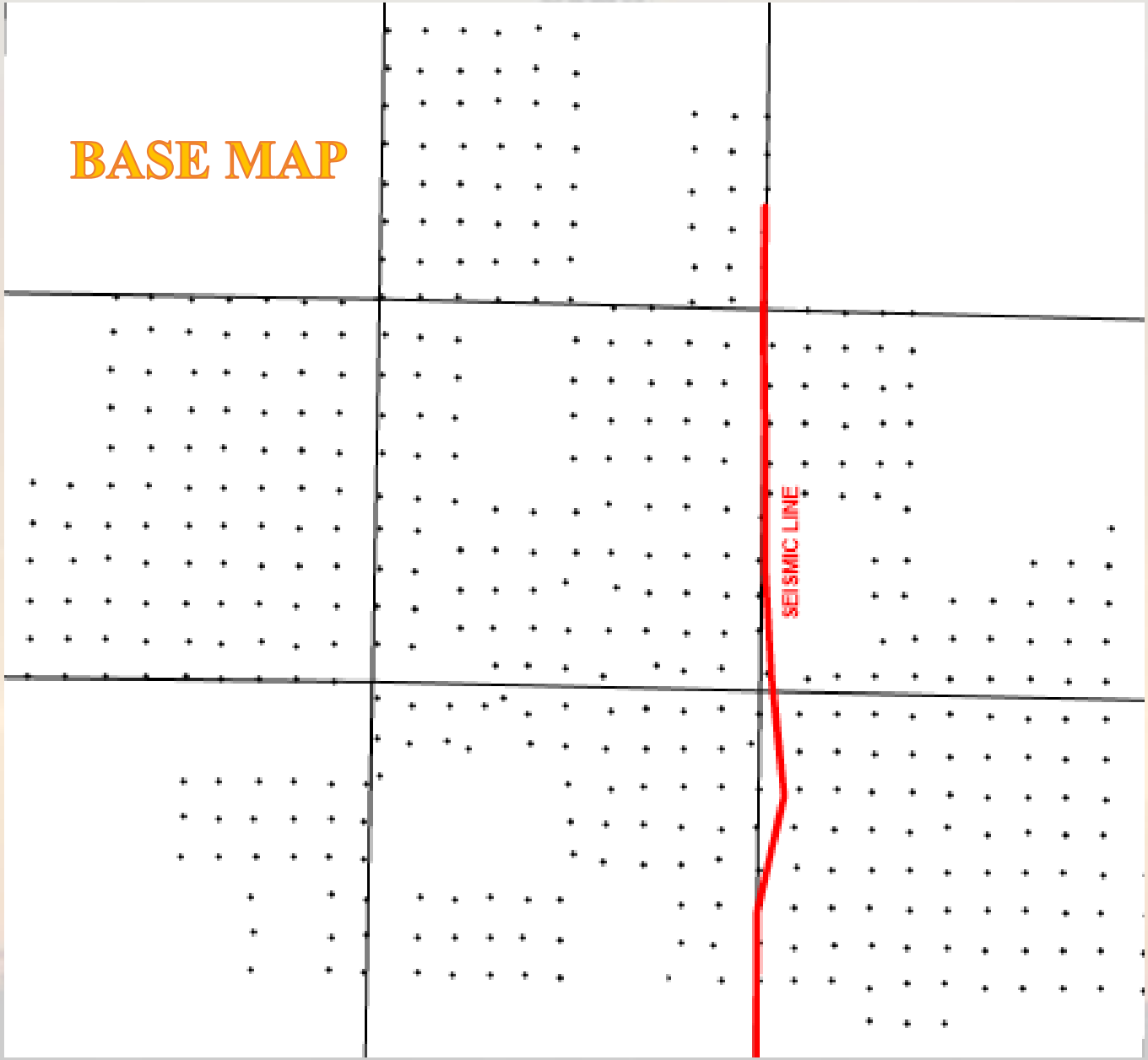
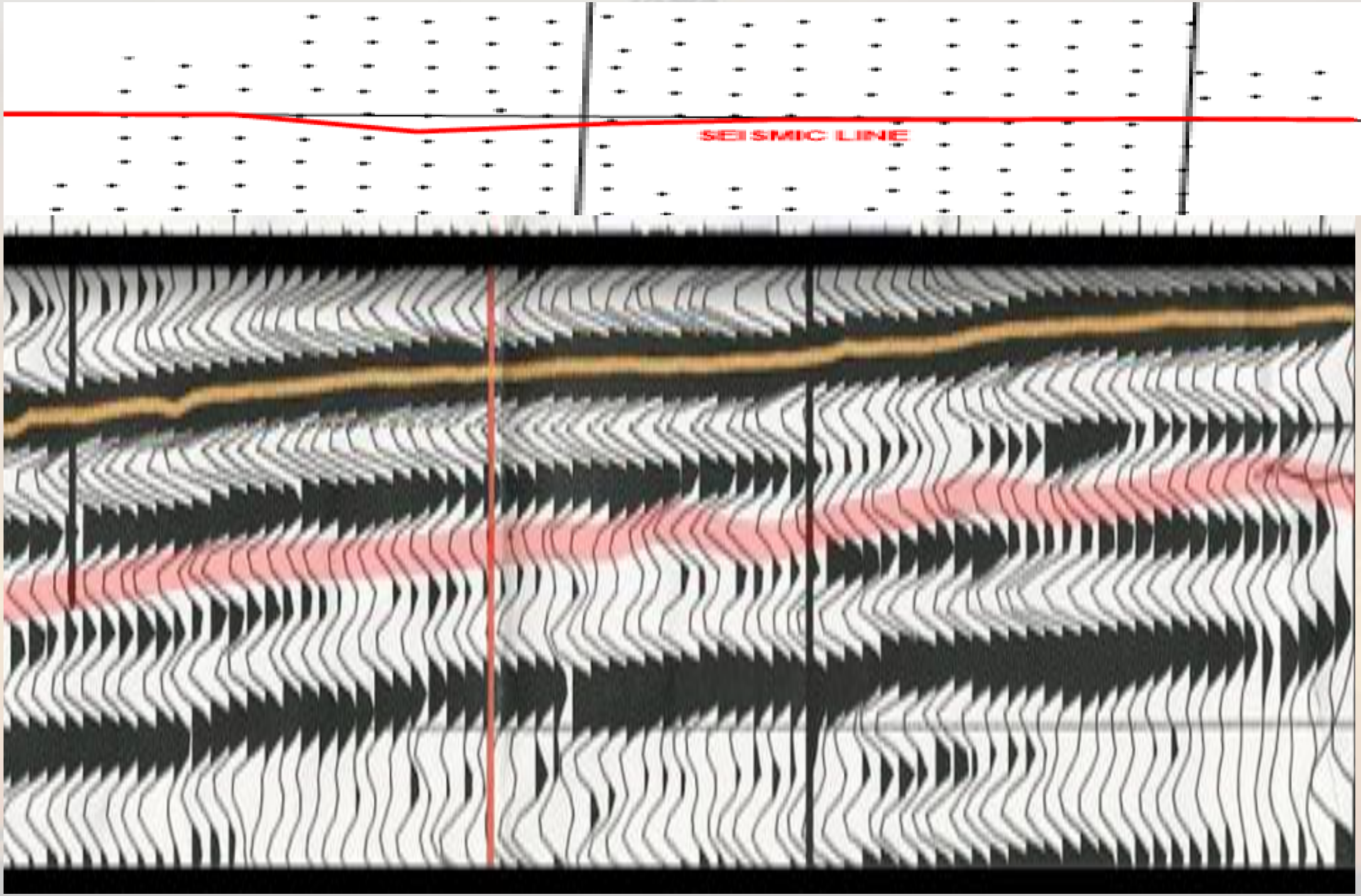
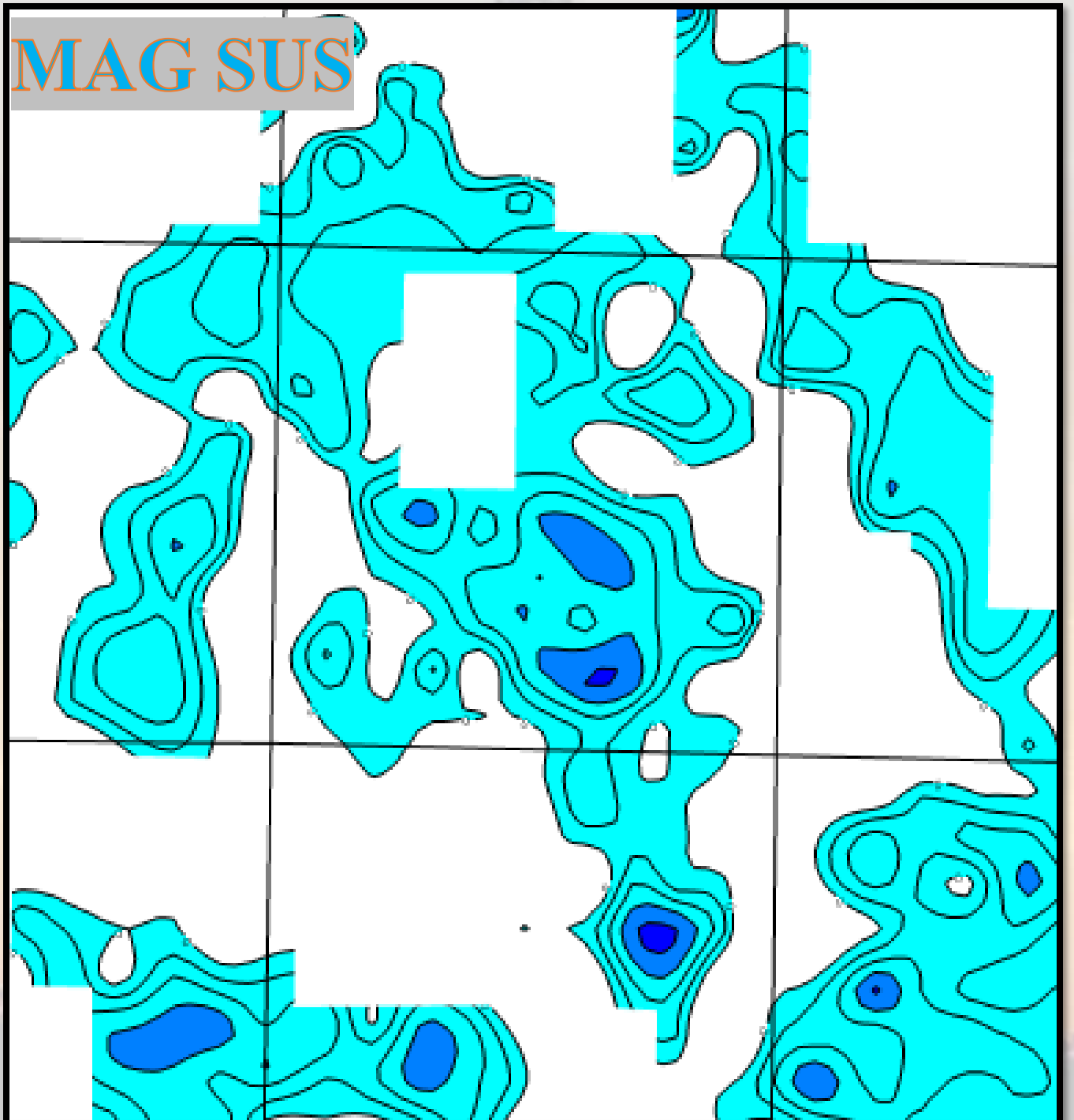
4000ft.
C.I. - 100ft.
SURVEY LINE
SURVEY LINE

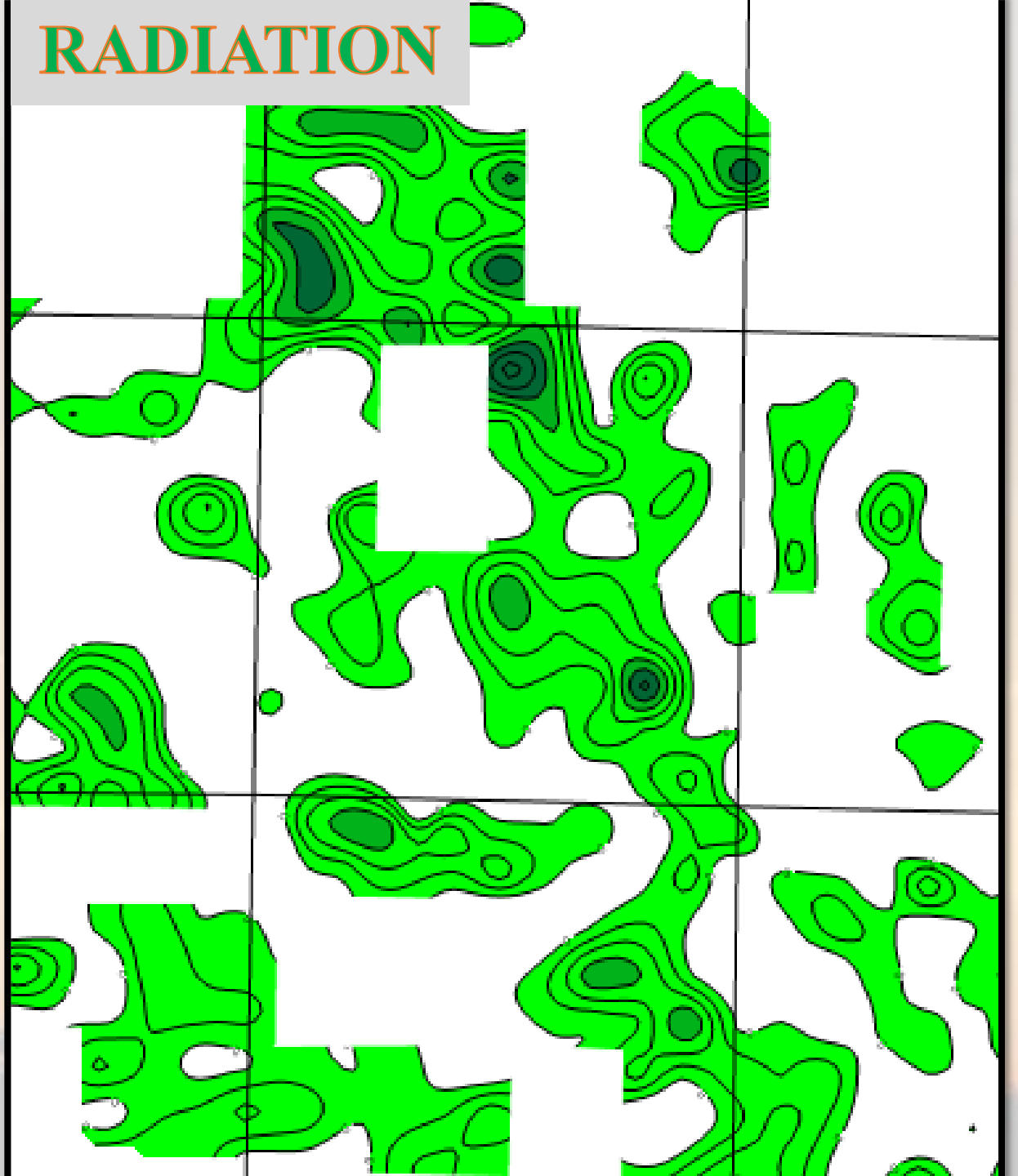
District 8A
Apical example 4300 feet




SEISMIC LINE


MAG SUS

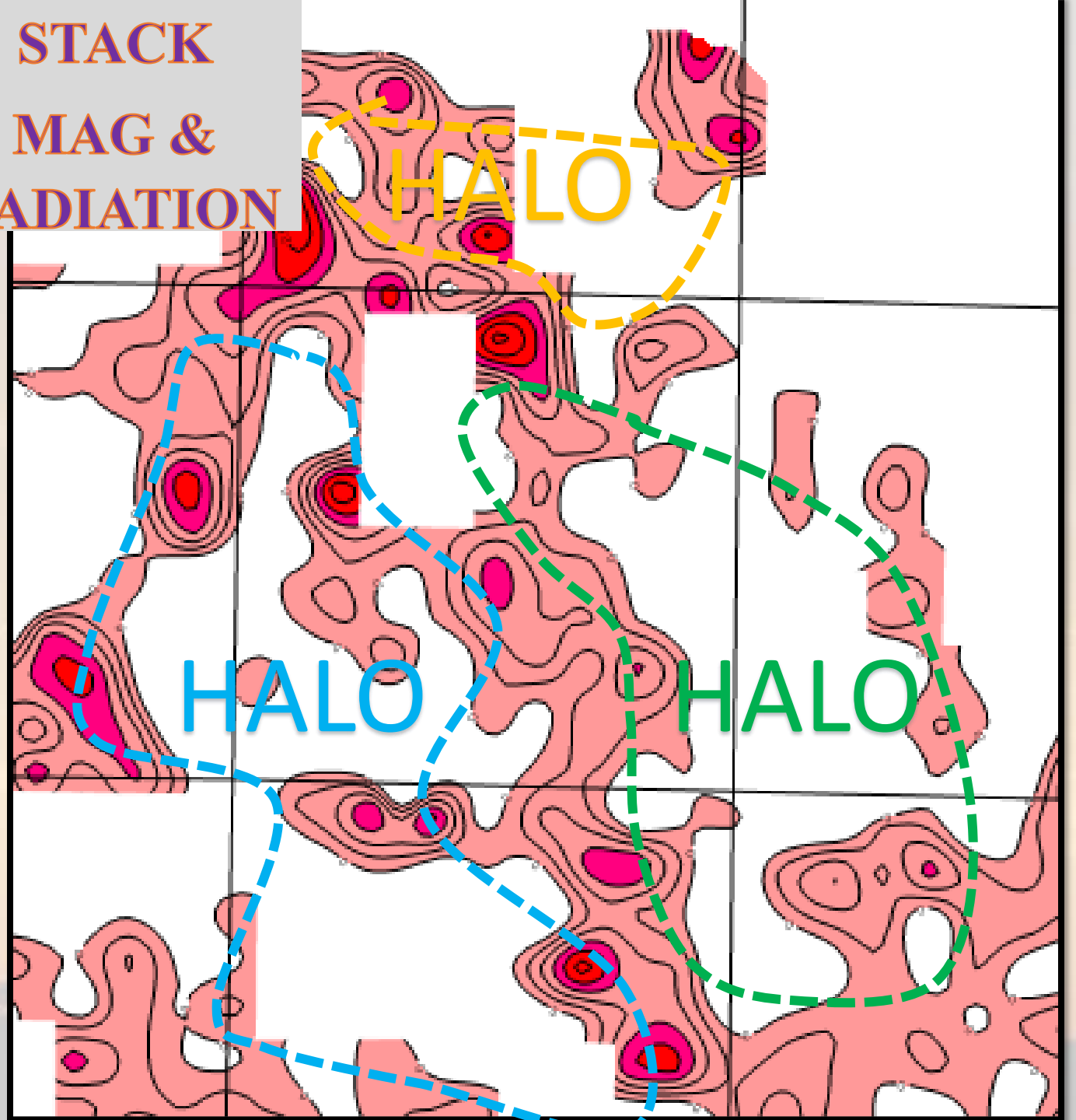
RADIATION



STACK

MAG &

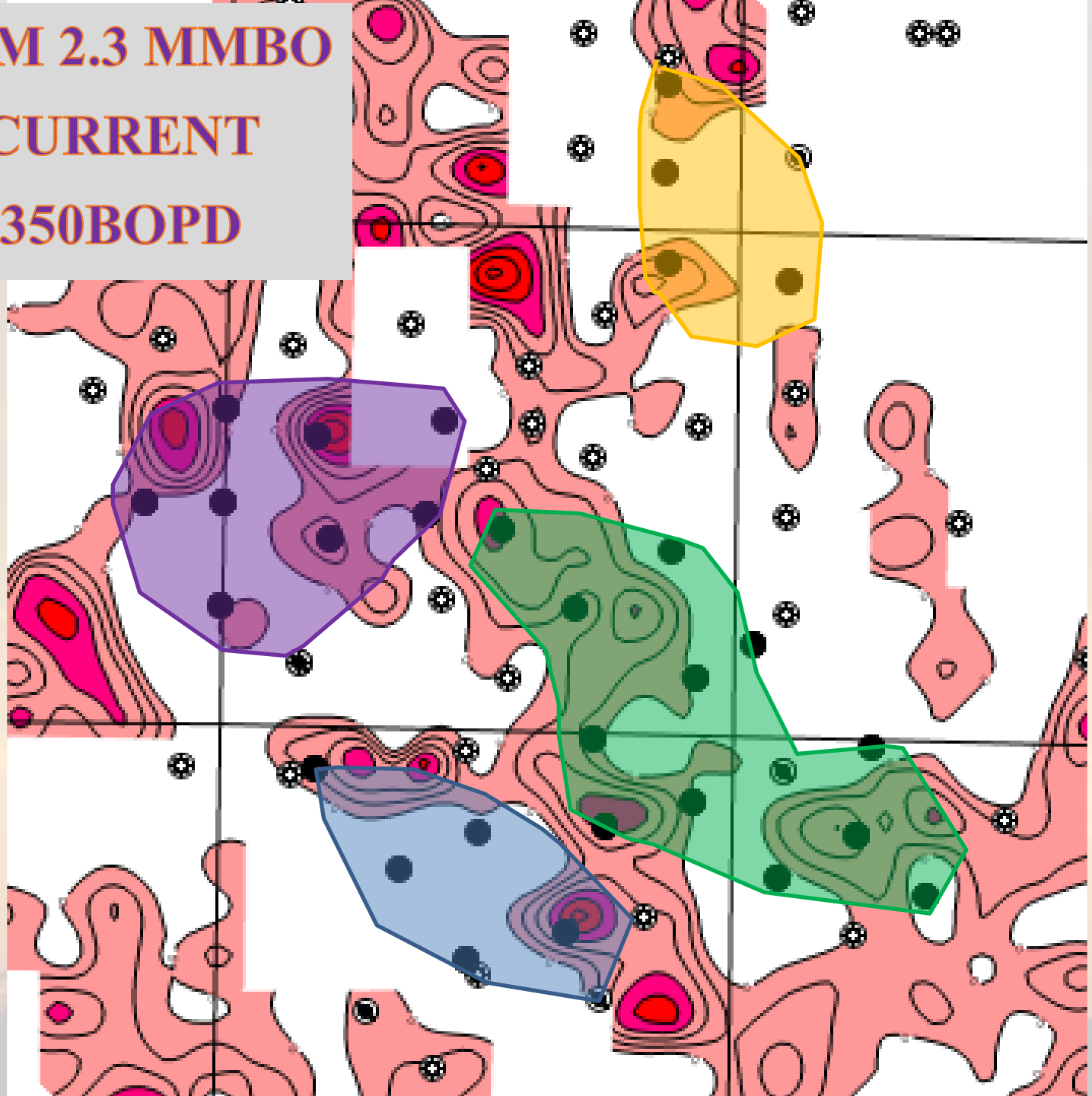
RADIATION



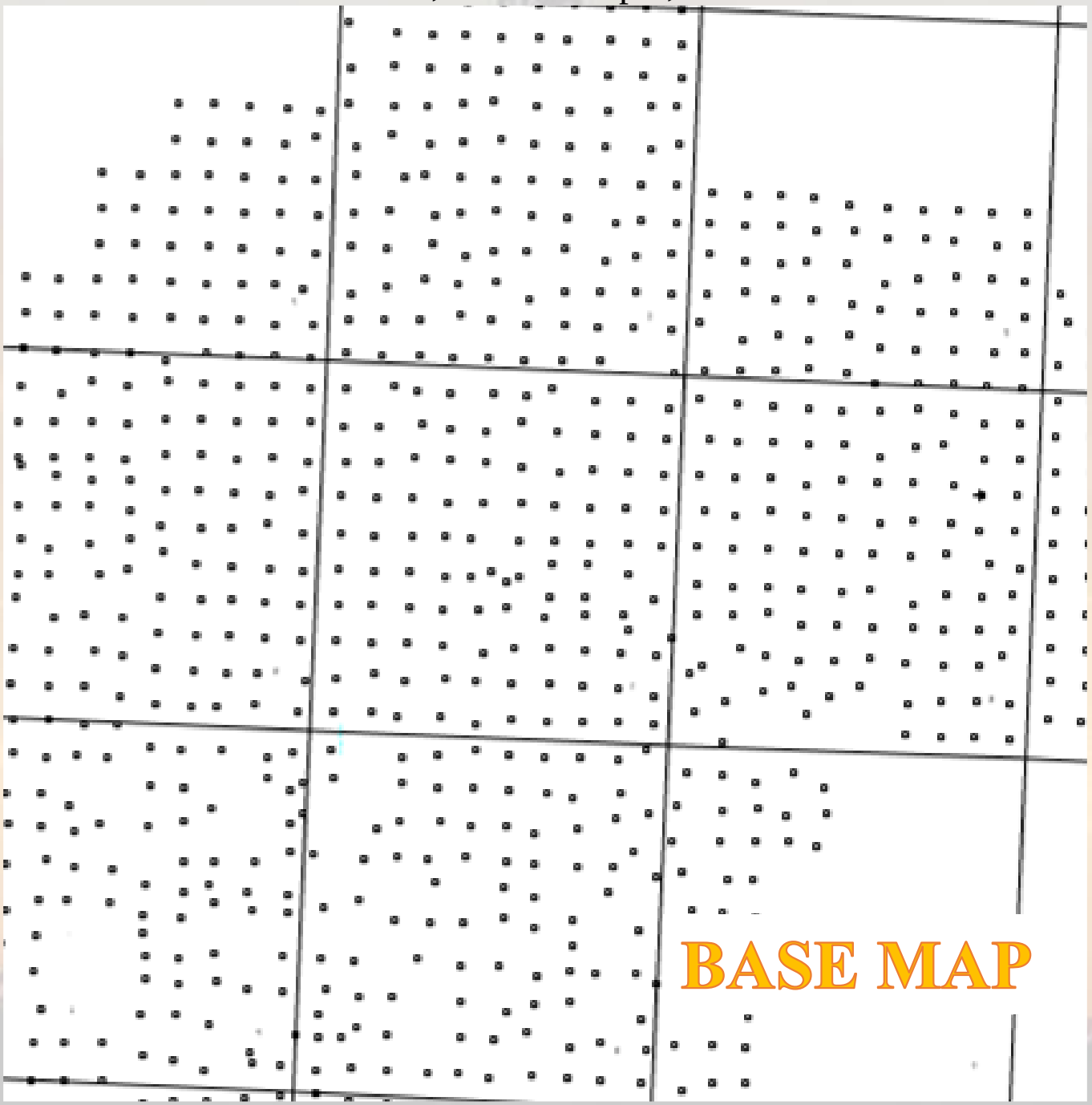
CUM 2.3 MMBO

CURRENT

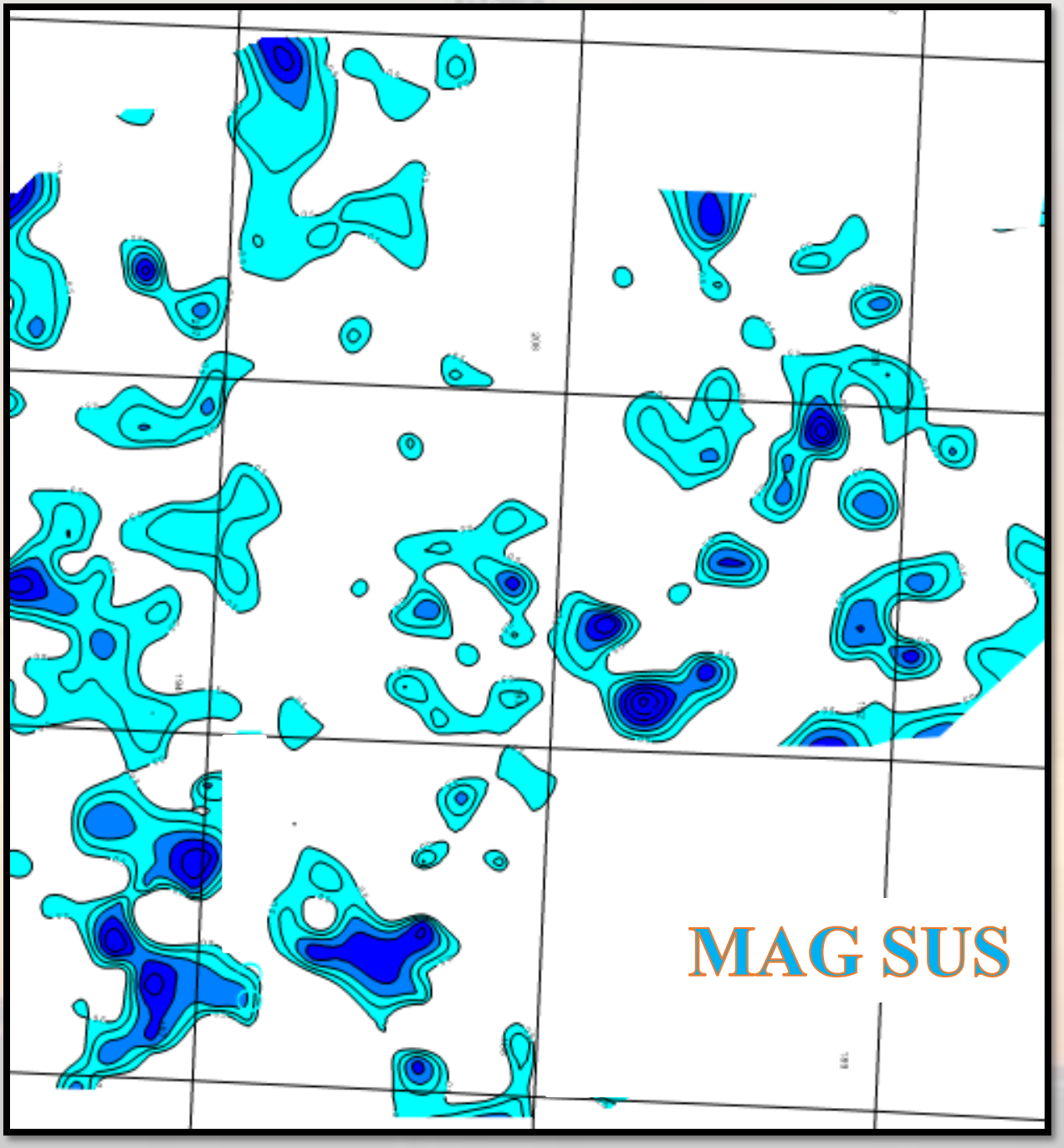
350BOPD



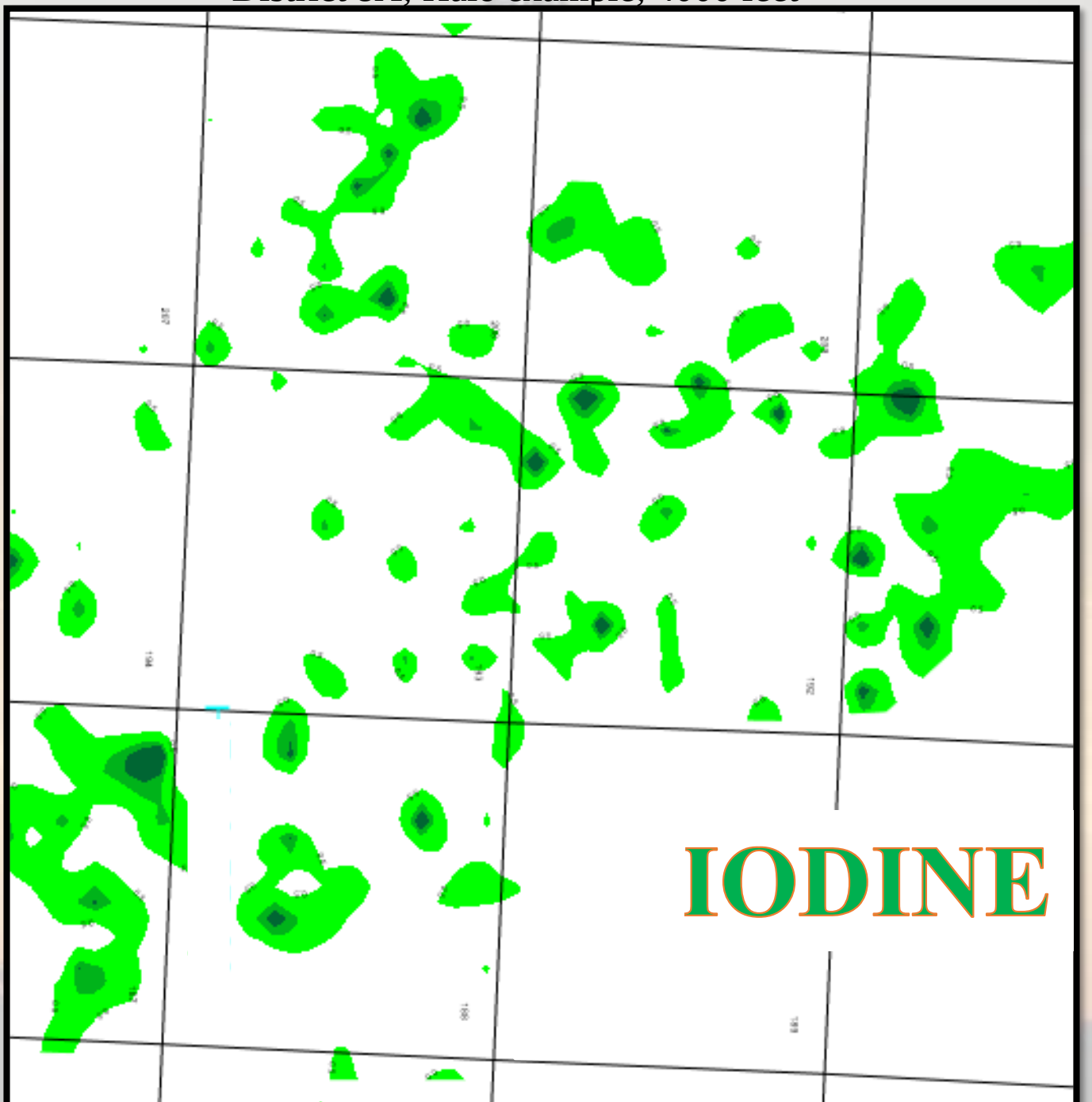
District 8A; Halo example; 4000 feet



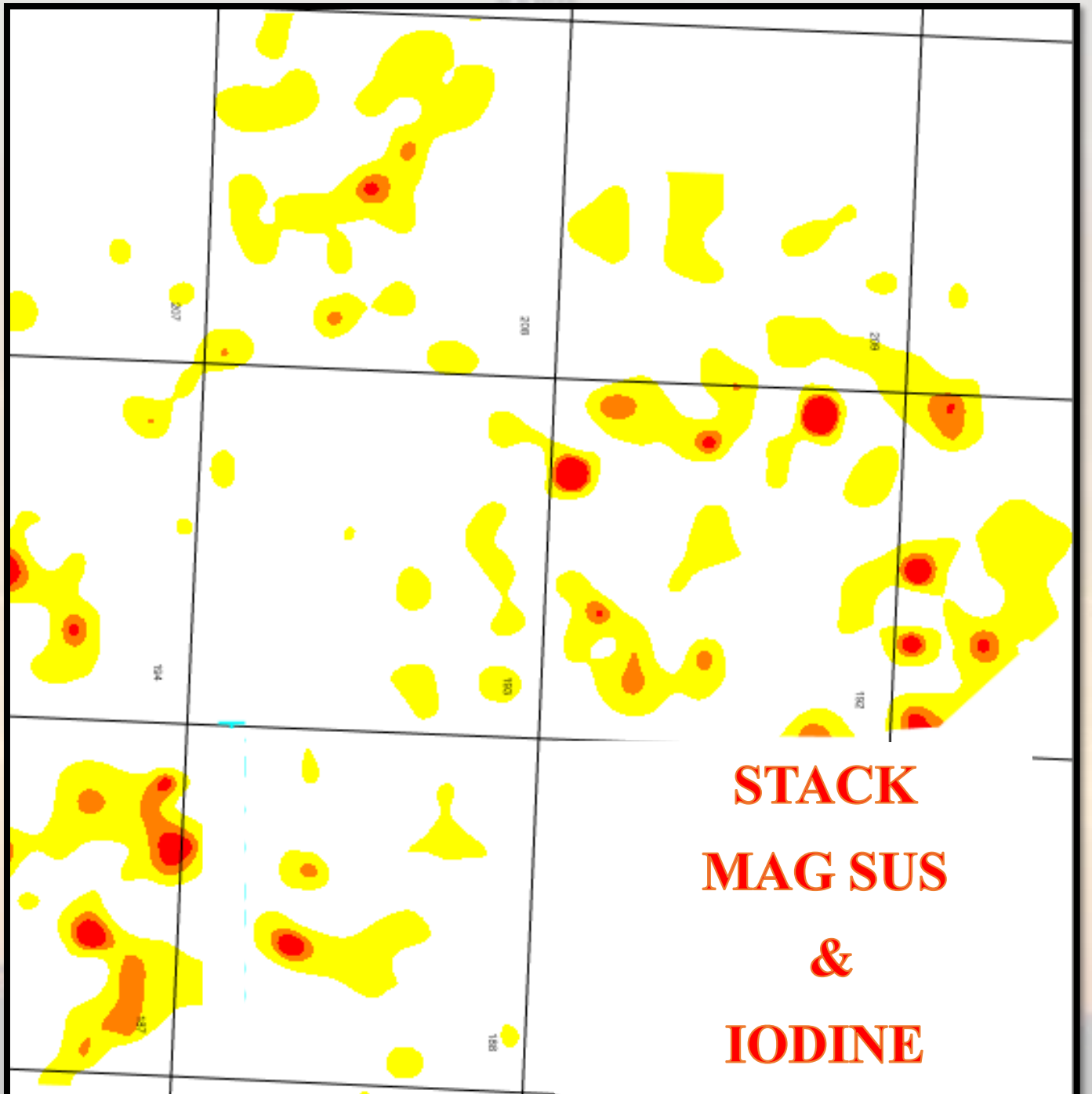
District 8A; Halo example; 4000 feet



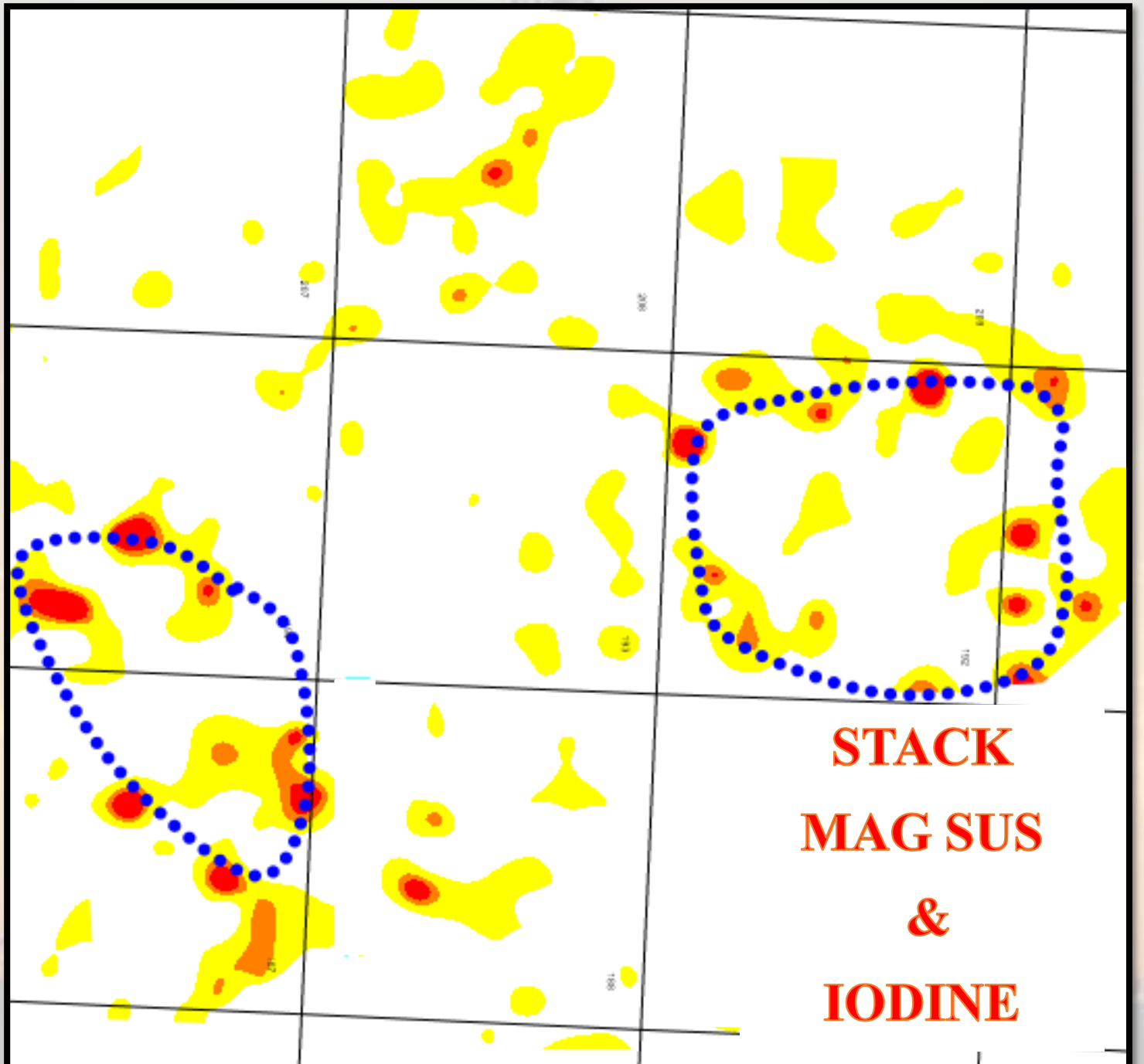
District 8A; Halo example; 4000 feet



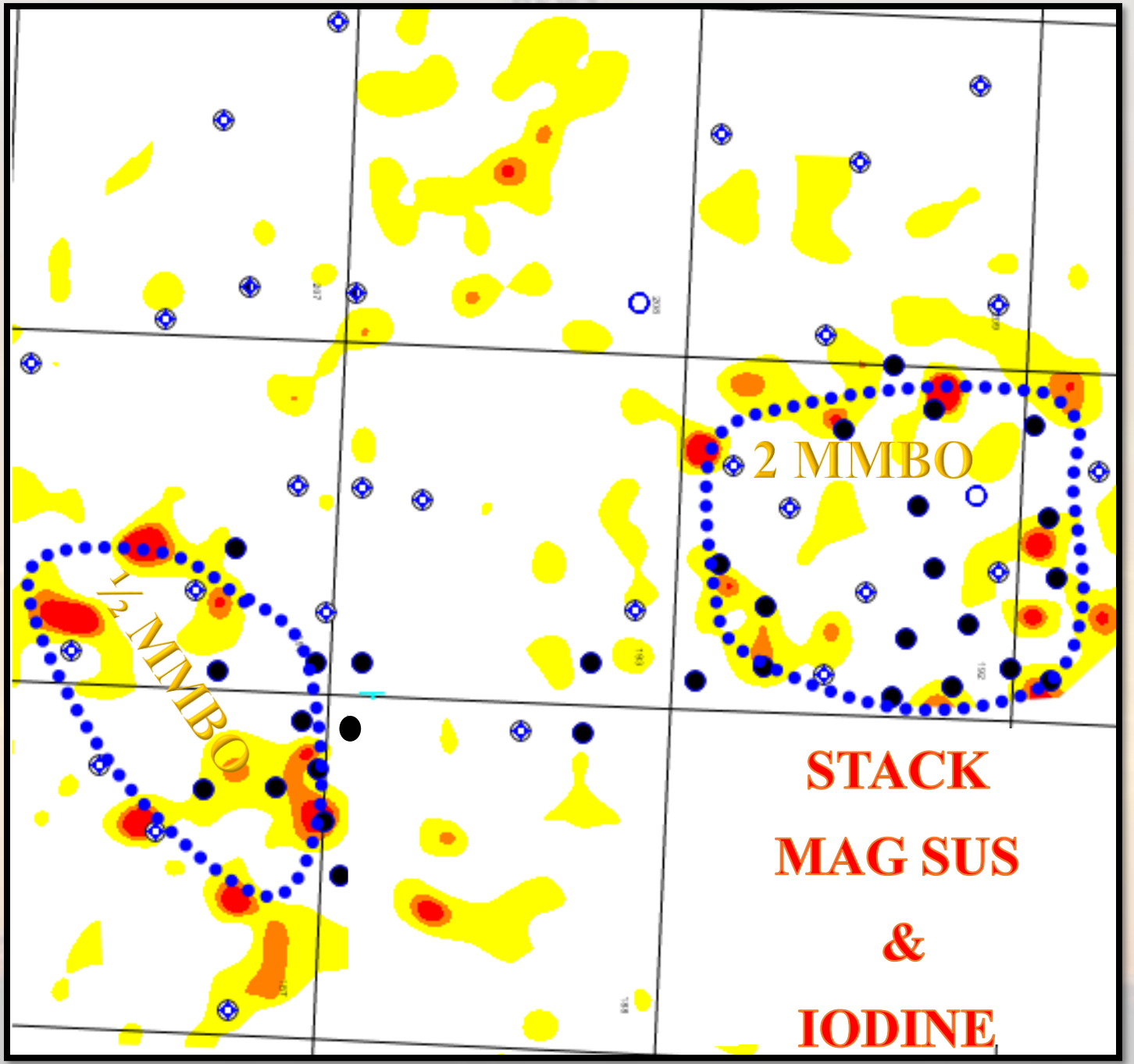
District 8A; Halo example; 4000 feet



District 8A; Halo example; 4000 feet



District 8A; Halo example; 4000 feet



SUMMERY

GEOCHEMICAL DATA IS NOISY.
STACKING TOOLS REDUCES NOISE
I STACK 3 TOOLS MINIMUM.

1. MAGNETIC SUSCEPTIBILITY - INDIRECT
2. RADIOMETRIC - INDIRECT
3. DIRECT MEASUREMENT OF BENZENE, BROMINE, OR BUTANE CONCENTRATIONS
4. IODINE OR XRF – EXPENSIVE ADD TO DATA BUT GOOD INFORMATION W/ TRACE ELEMENTS

DATA NEEDS TO BE ON A GRID GEOMETRY

1. GRID SHOULD HAVE MINIMUM OF 2 STATIONS WITHIN EXPECTED RESERVOIR WIDTH
2. 660’ X 660’ MAXIMUM SPACING
3. 528’ X 528’ NORMAL (RECON 528 X 1056)

ROADS ARE NOT FAVORABLE DUE TO CONTAMINATION ISSUES
ONLY SAMPLE NATIVE SOIL (GRASSY)

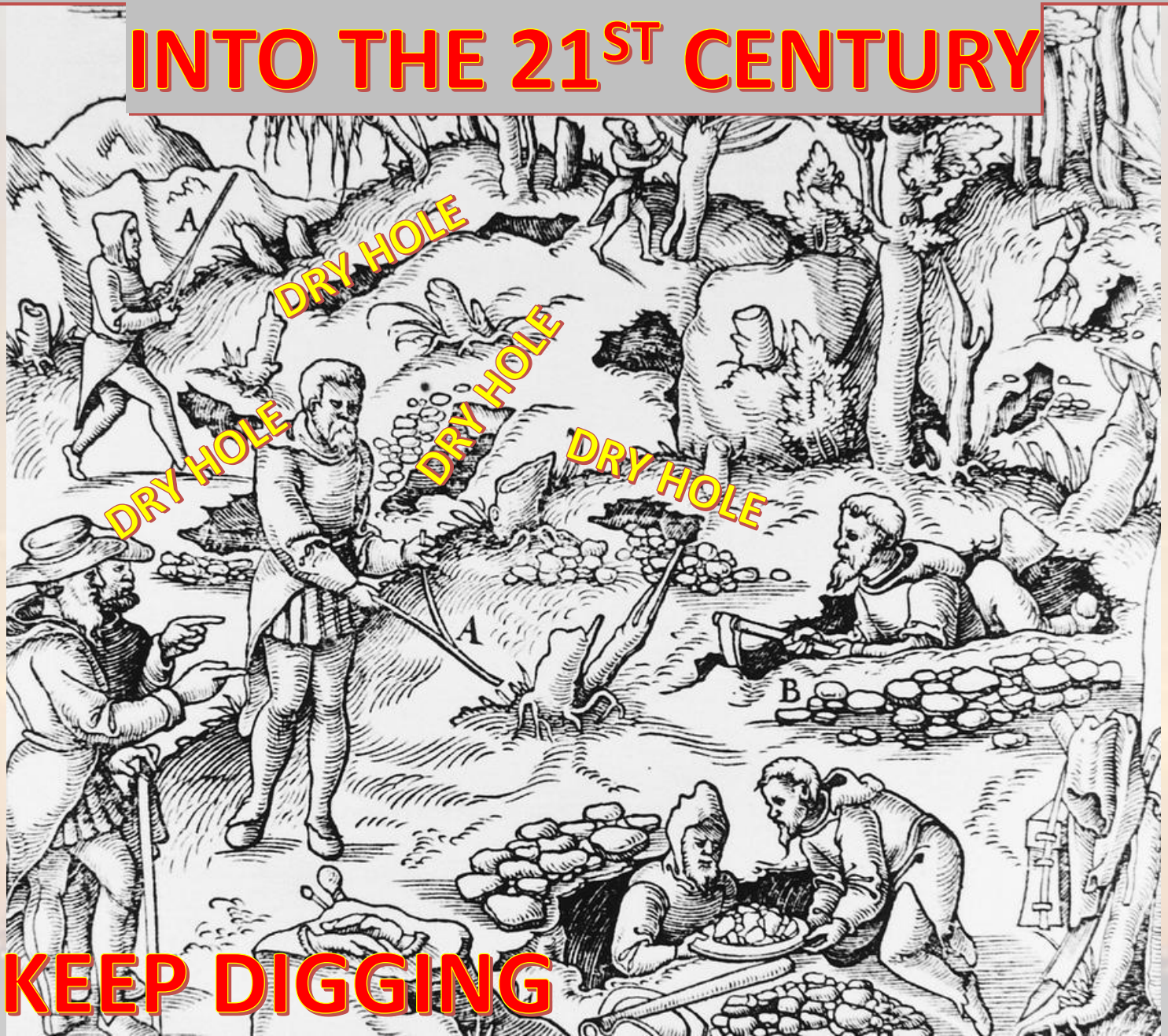
COST

3 TOOL COMBINATION

$6000 / SECTION + MILEAGE

TOO CHEAP NOT TO DO

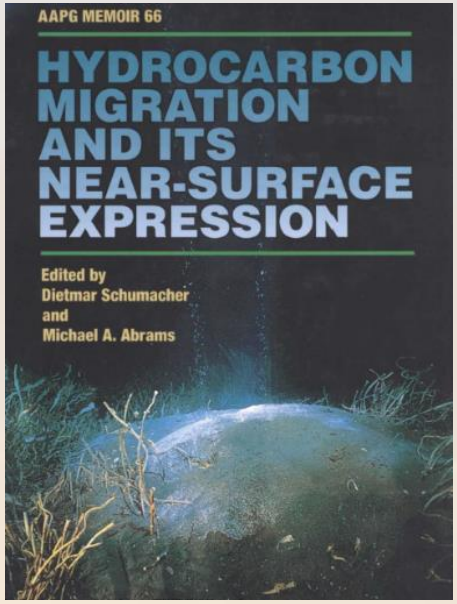
BRING YOUR EXPLORATION PROGRAM INTO THE 21ST CENTURY



KEEP DIGGING

MICROSEEP AS AN EXPLORATION TOOL

Publications such as "Hydrocarbon Migration And Its Near-surface Expression" published by the American Association of Petroleum Geologist, Memoir 66, detail hydrocarbon microseepage as a strong tool in finding hydrocarbon accumulations. Contributions by Conoco Inc., Pennzoil, Exxon, Phillips, and Shell show the attention the major oil companies give to hydrocarbon microseepage in their exploration programs.



"Soil Gas and Related Methods for Natural Resource Exploration" by Ron Klusman, Colorado School of Mines.

"Contrary to popular belief that 'hydrocarbon reservoirs absolutely do not leak', a large quantity of evidence has accumulated, indicating that gases can be transported from the depths of an oil and gas reservoir to the surface without significant dilution and dispersion."