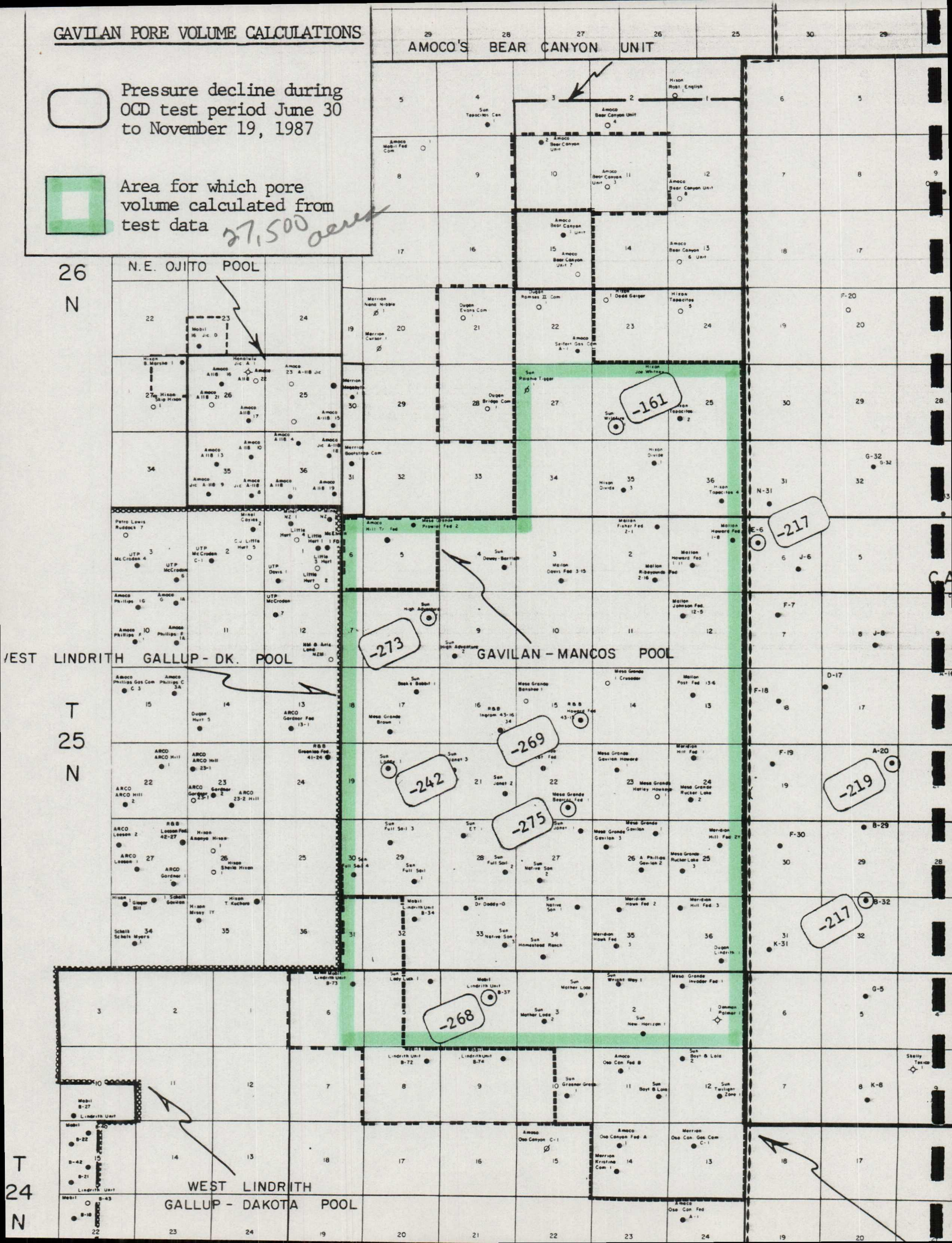
GAVILAN PORE VOLUME CALCULATIONS
Pressure decline during OCD test period June 30 to November 19, 1987
Area for which pore volume calculated from test data
27,500 acres
AMOCO'S BEAR CANYON UNIT
N.E. OJITO POOL
GAVILAN - MANCOS POOL
WEST LINDRITH GALLUP - DK. POOL
WEST LINDRITH GALLUP - DAKOTA POOL
26 N
T 25 N
T 24 N
-161
-217
-273
-269
-242
-275
-219
-217
-268

GAVILAN EFFECTIVE HYDROCARBON RESERVOIR SPACE

The OCC-ordered production and pressure test provided information - perhaps the most definitive and useful information - for determining effective hydrocarbon reservoir space in Gavilan.

The reservoir space is thought to be essentially of fracture porosity; and although the term "pore volume" is used sometimes herein, it is not intended to mean "porosity" as in matrix porosity.

The area selected for analysis is outlined on the plat on the facing page. Also shown on this plat are pressure declines within and near the area during the test period from June 30 to November 19, 1987.

The area contributing to production is not definitely known; and it is probable that the area did receive support from outside the boundaries shown - particularly in July some migration occurred from the east, and it seems probable that migration also occurred from the north.

Even so it is believed that the results obtained from the analysis are reasonable. They indicate an average pore volume in the range of .2 to .25 porosity feet.

It is probable that the pore volume does not exceed .3 porosity feet.

DETERMINATION OF EFFECTIVE HYDROCARBON PORE VOLUME * FOR GAVILAN

The most definitive information that can be determined from the OCC-ordered test period of July to November 1987 is Gavilan's effective hydrocarbon pore volume through the use of reservoir system compressibilities.

This has many virtues over the conventional material balance (or reservoir simulation) methods - and the results can be made just as accurately with a slide rule as can be obtained by the most sophisticated of computer programs. The accuracy here is dependent more on judgment of parameters used - such as area contributing to production - than on the program.

Attempts here to determine effective hydrocarbon pore volumes by conventional material balance methods are plagued by such problems as the following:

1. Migration away from Gavilan before it was drilled.

2. Migration to Gavilan following production.

3. Conventional material balance methods require accurate information of reservoir fluid (PVT) properties, such as initial bubble point pressure, formation volume factor, etc. (Different fluid analyses will give different results - and the engineers are not in agreement as to PVT data.)

4. Unknown amount of initial free gas in the reservoir.

5. Problem of "weighting" of absolute pressures by associated reservoir volume, as well as the error in determining absolute pressures themselves (as opposed to pressure decline during test).

6. Error for early production periods of indefinite value of formation compressibility.

* As used herein, "pore volume" means effective hydrocarbon reservoir space (believed to be essentially fracture porosity). It is not intended to mean "porosity" as in matrix porosity.

The above infirmities are minimized or eliminated by using only the test period data and reservoir compressibilities rather than conventional material balance methods and the entire production history (referring to numbered items above):

1 and 2: Although migration occurred from West Puerto Chiquito to Gavilan during the test period, it is believed small compared to overall migration (because wells were producing in both pools during the test).

3: The calculation is independent of bubble point and initial formation volume factor. Also compressibilities were high enough during the test that the resulting differences for the different PVT data are rather minimal.

4: Although one can approximate the amount of free gas resulting from oil production (by estimating ratio of production to initial oil in place and modifying by formation volume factors), the amount of free gas initially in the reservoir is more difficult to determine. For the test period compressibilities (and for determining effective hydrocarbon pore volume) it is not necessary to accurately know the initial free gas. Here again the compressibility of free gas and saturated oil provide counterbalancing effects. A wide range of free gas - as shown in the following calculation - gives only small changes in effective hydrocarbon pore volume.

5: Use of pressure differences (as opposed to absolute pressures) eliminate (as shown before) some of the errors caused by the inherent errors in absolute pressures. A large part of the affected reservoir volume was declining at about the same rate - so it is not necessary to accurately know these absolute pressures to apply the compressibility solution.

6: Total system compressibility during the test period was high enough that errors in formation compressibility are not as significant as for material balance calculations of early production.

METHOD OF CALCULATING PORE VOLUME FROM TEST PERIOD DATA

Pore volume was calculated from system compressibilities by simply recognizing the elements of compressibility by its definition:

$$C_t = \frac{\Delta V}{V\,\Delta P}$$, and solving for V

$$V = \frac{\frac{\Delta V}{\Delta P}}{C_t}$$

Where ΔV is reservoir volume produced (barrels used here)
ΔP is pressure decline during the production
C_t is system compressibility

$$C_t = C_{os}\,S_{os} + C_g\,S_g + C_f$$

(No undersaturated oil here, and elimination of connate water will have negligible effect)

Where C_{os} = compressibility of saturated oil
C_g = compressibility of free gas
C_f = formation compressibility

Once the reservoir volume is determined, volume per acre is estimated from an assumed drainge area, and from this, pore volume, expressed here as porosity times feet.

Also shown for the various assumed properties are initial stock tank barrels per acre (for assumed condition of no free gas initially).

CALCULATION OF GAVILAN PORE VOLUME FROM PRESSURE AND PRODUCTION DATA OF THE OCD-ORDERED TEST PERIOD JUNE 30 TO NOVEMBER 19, 1987

(FOR THAT PART OF GAVILAN SHOWN ON PLAT)

Pressure Decline ± 210 Psi

Oil Production ± 440,000 Stock Tank Bbls

Gas Production ± 2118 MMCF

Average GOR ± 4800 CF/Bbl

Average Reservoir Pressure ± 1020

Compressibility of Saturated Oil 490 x 10^{-6} (Loddy sample)

Compressibility of Free Gas 900 x 10^{-6} (Loddy sample)

Area of Production ± 27,500 acres (41 sections + 7 partial sections)

Production "coefficient" (bbls/psi)
Stock Tank Bbls/Psi 2100

Reservoir Bbls/Psi 28,000
(2.76 Reservoir Bbls/MCF)
(For GOR = 4800
Rs 450, Bo 1.32
13.2 Reservoir Bbls/Stock Tank Bbl)

Free Gas Fraction of Pore Volume (Sg) (1)	Saturated Oil Fraction of Pore Volume (So) (2)	Comp. of Formation (Cf) (x 10^{-6}) (3)	Total Hydrocarbon System Compress. (x 10^{-6}) (4)	Hydrocarbon Reservoir Volume (MM Res. Bbls) (5)	Original Oil in Place Stock Tank Bbls at 1.38 FVF (MM Bbls) (6)	Reservoir Volume (Bbls/Acre) (7)	Initial Stock Tank Bbls/Acre at FVF of 1.38 (Bbls/Acre) (8)*	Pore Volume Porosity-Feet (øh) (9)
.05	.95	15	525	53	39	2000	1900	.25
"	"	100	610	46	33	1700	1200	.22
.10	.9	15	545	51	37	1900	1400	.24
"	"	100	630	44	32	1600	1200	.21
.15	.85	15	565	50	36	1800	1300	.23
"	"	100	650	43	31	1600	1100	.20

* If no free gas.