Lab 6.
Isopach Mapping

Objective

To estimate the hydrocarbon pore volume of a reservoir

Background

An isopach is a line representing equal stratigraphic thickness, and an isopach (or isopachous) map is one that shows bv means of isopachs the variations in true strati-graphic thickness of a stratum, formation, or group of formations. The subsurface isopach map is based primarily on formation thicknesses determined from well cuttings, cores or geophysical logs. Although isopachs must be drawn to agree with thicknesses plotted on the map, their spacing and the nature of thickening and thinning may be guided by other known facts concerning the source of sediments, their relative rates of deposition, truncation, and so forth. An isopach map drawn strictly to the numerical values and without regard to the geologic reasons for thickening and thinning of formations, is likely to present a picture difficult to integrate or reconcile with other geologic facts.

An example of an isopach map is shown in Figure 1. Close spacing of contours from zero to 200 feet on the west side of the map indicates the area of truncation where the formations are tilted along the granite mass. The conclusion is that the higher rate of thinning is caused by truncation of upturned edges of the strata, and the close spacing of contours is, therefore, maintained parallel to the granite area. Around the uplift on the east side of the map area, control points indicate a high rate of thickening, with the uplift being the source of these sediments.

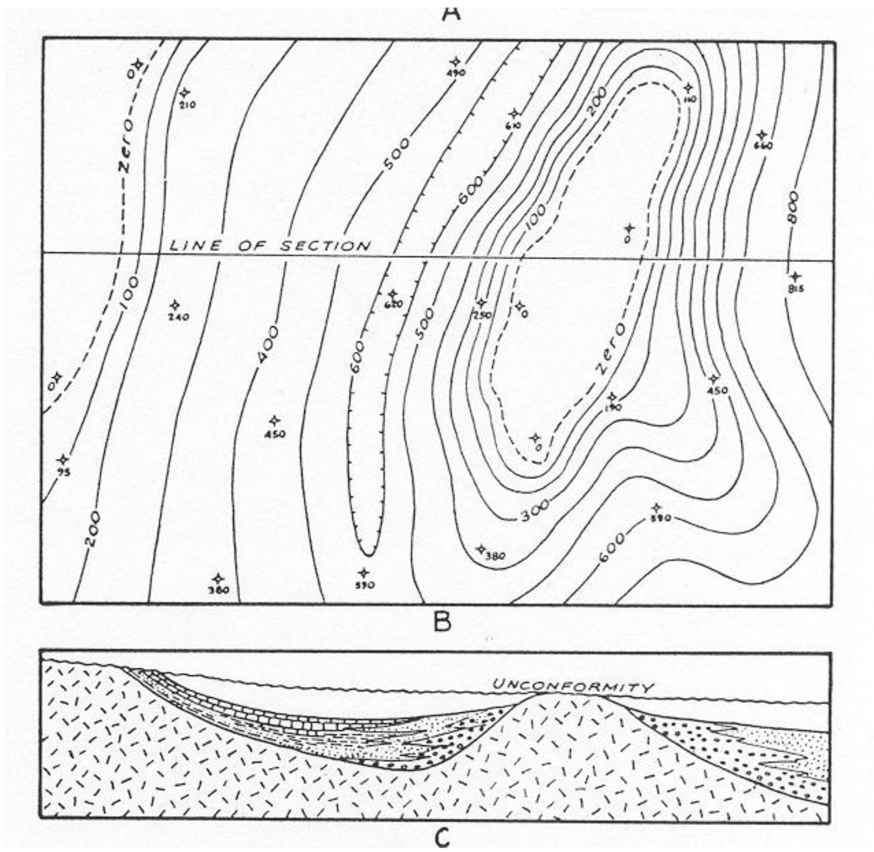

Figure 1 Top and cross-sectional views of an isopach map of the thickness of sediments between an unconformity and basement.

A common source of error in subsurface isopach maps is the too great apparent stratigraphic interval caused by steeply dipping strata at the point where the well is drilled. Obviously, a correct interval is obtained in a straight hole only where the strata are horizontal. Since most wells are drilled on structures, there are many opportunities for them to penetrate formations where appreciable dips exist; if dips are steep, the error in interval may be large enough to affect the regional aspects of the isopach map; there is little doubt that apparent thinning of section on the tops of some structures is the result of this condition. As an extreme case consider a deviated well in dipping beds as shown in Figure 2. The measured thickness (MT) greatly exceeds both the true vertical thickness (TVT) and the true stratigraphic thickness (TST) of the formation of interest. The result will impact the geologists ability to correlate from well-to-well and interpret the depositional history, and will impact the engineers ability to estimate the volume of hydrocarbons in place and flow capacity of a well.

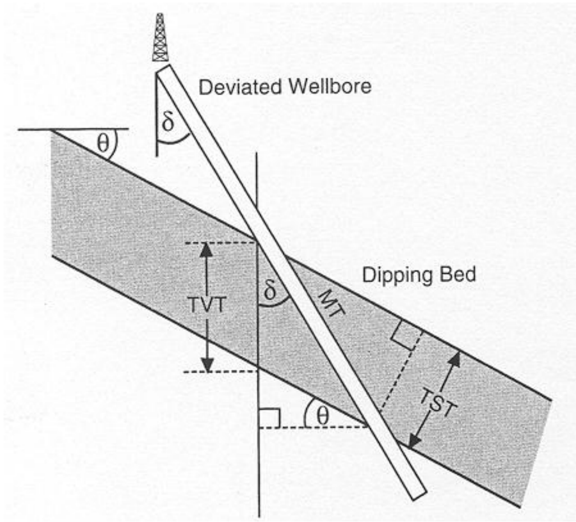

Figure 2 TVD principle for a deviated well and a dipping bed

Although subsurface maps representing drilled thicknesses are commonly called isopach maps, a more precise term is isochore. An isochore map is one that shows by contours drilled thicknesses of formations without regard to true stratigraphic thicknesses. The term is not ordinarily used but is mentioned because it appears occasionally in geologic literature.

Isopach and isochore maps are generally used:

a. for predetermining drilling depths to specific horizons in wildcat wells;
b. to locate buried structures in regions where formations habitually become thinner over structural crests.
c. In estimating the elevation of a datum bed below the total depth of a well that penetrated a higher known stratigraphic horizon.
d. To calculate the volume of oil in a formation

Figure 3 shows a structure contoured on the top of a producing formation. A few dry holes have been drilled on the flanks of the structure below the oil-saturated portion of the reservoir, and by means of these holes, the oil-water contact is established at a structural elevation of 660 feet. This contact is shown by the heavy dashed line on the map and also in the cross section. Since the thickness of the oil column is less than the thickness of the reservoir rock, the computation of the volume of saturated sandstone is simple, because the isopach map of the saturated rock is exactly the same as the structure map, with only the contour values being changed. It is evident in the cross section that the extra structural contour (oil-water line) of 660-foot elevation is the same as the zero isopach contour for the saturated zone. Likewise, the 700-foot structural contour becomes the 40-foot isopach line, the 800 becomes the 140, and so forth. The thickest part of the zone is on the top of the structure at an elevation of 1,050 feet, here the thickness is 390 feet.

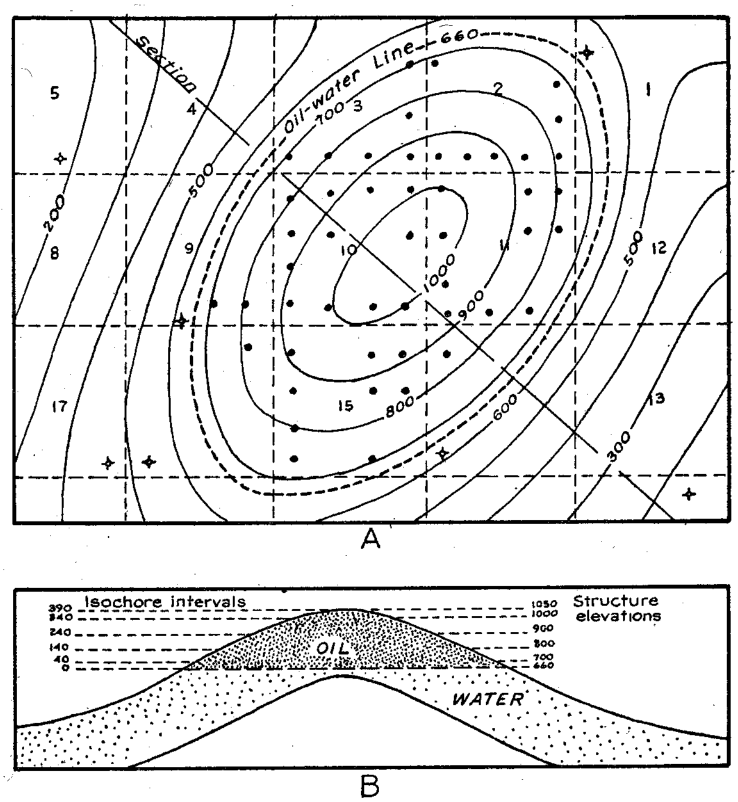

Figure 3 Structure map and corresponding isopach of the producing interval.

Two methods will be applied in this lab to estimate volumes from an isopach map. The first will be to use a planimeter to estimate the average thickness within the isopach area. The second method utilizes a software package that includes digitizing the isopach map and applying geostatistics to determine the volumetrics.

Data Analysis

1) Per Well

Determination of hydrocarbons-in-place can be calculated from either of the following equations.

$$
\begin{aligned}
HIP &= c\frac{A}{B_{oi}}\sum_{i=1}^{n} h_i \phi_i (1-S_{w_i}) \\
&= c\frac{Ah_p\bar{\phi}(1-\overline{Sw})}{B_i}
\end{aligned}
\tag{1}
$$

where c is a constant equal to 7358 for oil and 43560 for gas, respectively and B is B_o for oil and B_g for gas. The steps to evaluate the potential of a well are:

a. apply cutoffs to determine intervals which meet criteria.
b. Apply the appropriate averaging technique
c. apply a recovery factor to remaining intervals to account for displacement efficiency.

Consider the following hypothetical example.

Depth, ft	h_i	ϕ_i	$\phi_i\, h_i$	S_{wi}	$\phi_i\, h_i\, S_{wi}$	Remarks
1600-02	2	0.02				Tight
1602-04	2	0.10	0.2	0.20	0.04	Pay
1604-06	2	0.20	0.4	0.30	0.12	Pay
1606-08	2	0.15	0.3	0.60	-	Water

Since log and core data is acquired on a depth basis, the parallel model is applicable.

$$h_p = \sum_{i=1}^{2} h_i = 4'$$

$$\bar{\phi} h_p = \sum_{i=1}^{2} \phi_i h_i = 0.6'$$

$$\left(\bar{\phi} h_p\right)\overline{S_w} = \sum_{i=1}^{2} \phi_i h_i S_{wi} = 0.16'$$

Recovery factor can be calculated by:

(i) material balance (requires history)
(ii) core tests (requires special core analysis)
(iii) log analysis (easy but not precise)

$$(RF)_{wd} = \frac{S_{xo} - S_w}{1 - S_w} \tag{2}$$

$$(RF)_{dcp} = \frac{1}{2}(RF)_{wd} \tag{3}$$

correlations, which are a function of drive mechanism, lithology, and GOR.

2) Per Field or Area

Equation 1 can be used to determine hydrocarbons-in-place on a fieldwide or area basis, but with a slight difference. Consider the following cases.

(i) Constant properties

The simpliest case is to assume constant properties (net pay, porosity, etc) throughout the reservoir. This relies on performing appropriate averaging techniques, such as the following,

$$\bar{h} = \frac{\sum_{i=1}^{N} h_i}{N}, \qquad (4)$$

where h_i is the thickness for well i, N is the number of the wells, and $\bar{h}$ is the average thickness.

(ii) Variable properties

In this case each well has a value of the property, which is mappable (isopach) within the areal plane. Planimetering and digitizing are examples of this mapping. Three types of isopach maps can be constructed:

a. net pay isopach reveals the distribution and areal extent of the net pay only. For estimating hydrocarbons-in-place, both average porosity and saturation are necessary.
b. Pore volume map (ϕh) provides the distribution relative the storage capacity of the formation. In this case, an average water saturation is needed.
c. Hydrocarbon pore volume map ($\phi h S_o$) exhibits the extent of the hydrocarbons within the porous rock.

Class Exercise

1. Post each well of the following table with the correct value of net pay on the attached map.
2. Contour the map using a 30 feet contour interval (isopach map).
3. Include title box and legend

Well #	Location	Survey	Block	Section	Net Pay, ft
1	1980 FSL, 1980 FEL	PSL	BLK 27	6	49
2	k	PSL	BLK 27	5	0
3	SE NW	PSL	BLK 27	7	101
4	1980 FNL, 1980 FWL	PSL	BLK 27	8	34
5	J	PSL	BLK 27	9	0
6	SE NW	PSL	BLK 27	17	0
7	1650 FNL, 1980 FEL	PSL	BLK 27	18	13
8	J	PSL	BLK 28	1	0
9	NW SE	PSL	BLK 28	12	38
10	1320 FNL, 1320 FEL	PSL	BLK 28	13	158
11	NE	PSL	BLK 28	14	0
12	G	PSL	BLK 28	24	0