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PRE-SALE EVALUATION OF HYDROCARBON POTENTIAL

By

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INTRODUCTION

The Division of Geological and Geophysical Surveys (DGGS) is responsible for the pre-sale evaluation of the oil and gas potential of areas scheduled in for the State's oil and gas lease sale program. This evaluation process involves years of work on the part of the geologists and geophysicists, acquiring and analyzing geological and geophysical data. Once the evaluation is completed results undergo economic analyses by the Division of Oil and Gas (DO&G). Both the geological and economic analyses are presented to the Commissioner of Natural Resources so that sale conditions can be determined; these are designed to maximize the State's revenue from the sale and from any subsequent production.

This booklet explains DGGS's procedure for pre-sale evaluations. In order to understand the work done it is necessary to be familiar with the basics of petroleum geology and seismic reflection theory.

PETROLEUM GEOLOGY

State oil and gas lease sales are scheduled for areas known to be, or suspected to be sedimentary basins -- areas in which large volumes of sediments have been deposited. Prior to a sale an area is subjected to intensive investigation by petroleum geologists. Their work consists of mapping the stratigraphic rock units or formations, measuring the thickness of these formations, determining their dip (the angle at which they plunge into the earth), studying the relationship between the different rocks, and, most importantly, determining the presence and quality of source rocks and reservoir rocks.

Source rocks are the rocks in which hydrocarbons are formed, normally shales and limestones. Hydrocarbons are formed when organic-rich sediments have been subjected to heat and pressure due to burial. Reservoir rocks are the rocks in which hydrocarbons are contained, normally sandstones and altered limestones.

The geologists collect rock samples in the field and have them analyzed to determine their geologic parameters; they need to learn about the source rock characteristics, and about the porosity and permeability of the reservoir rocks. Porosity is the amount of pore space between the grains of the rock. Fluid is trapped within these pores, and this is where the hydrocarbons will be found. Greater porosity would allow for more hydrocarbons to be present within the rock. However, merely having good porosity is not enough; the hydrocarbons need to be free to move throughout the pores within the rock. This is the property of permeability. Only if a rock has good permeability can the hydrocarbons be easily recovered; low permeability prevents the hydrocarbons from flowing through the rock.

Hydrocarbons will migrate out of the source rocks into the reservoir rocks where they can be recovered if their flow is impeded by a trapping mechanism. It is the job of the geologists to determine which type of traps to expect in an area. The simplest trapping mechanisms are shown in Figure 1. The anticlines (1A and 1B) will trap the oil if the rock layer above the reservoir rock is impermeable. Oil can be trapped against a fault plane (1C and 1D), however, these faults could also provide a path for the oil to travel out of the reservoir bed. The anticlines and faults are called structural traps. Figure 1E shows a stratigraphic trap, in which the oil is trapped by an impermeable bed that truncates the reservoir rock. It is important to remember that traps in the reservoir rock may or may not contain oil; the only way to find out is to drill a well.

In order to complete the evaluation of the area the geologists must also be able to "see" beneath the surface. This is accomplished if there are wells in the area. Well logs (Fig. 2) from these wells are obtained by lowering devices into a borehole and determining various parameters of the surrounding rocks utilizing electrical currents, radiation, sound waves, etc.

By studying these logs the geologists can determine the depths to the formations, the thicknesses of these formations, and whether there are any hydrocarbons present. They can calculate the porosity of the rock, estimate the permeability, etc. Well logs are the most important tool available to the petroleum geologist. Lack of wells in an area would introduce a very large risk factor into the evaluation process (risk factors will be discussed later).

Once well logs within the area have been interpreted (formation top locations picked) the geologists construct geologic cross sections tying the wells together (see Fig. 3). The geologists will also generate sand maps, porosity maps, resource trend maps, etc; all of these are helpful in evaluating the resource potential of an area.

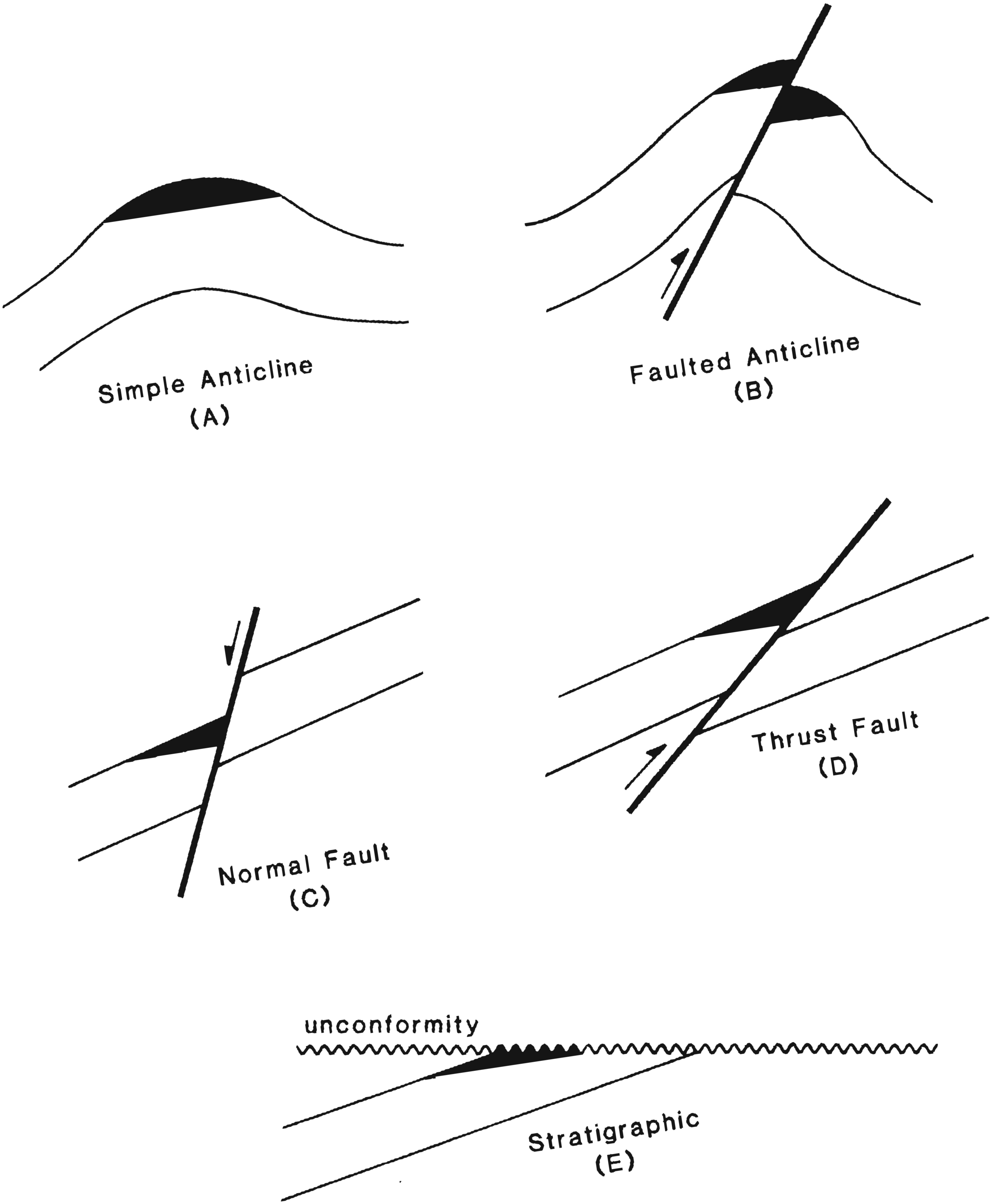

Figure 1. Simple trapping mechanisms

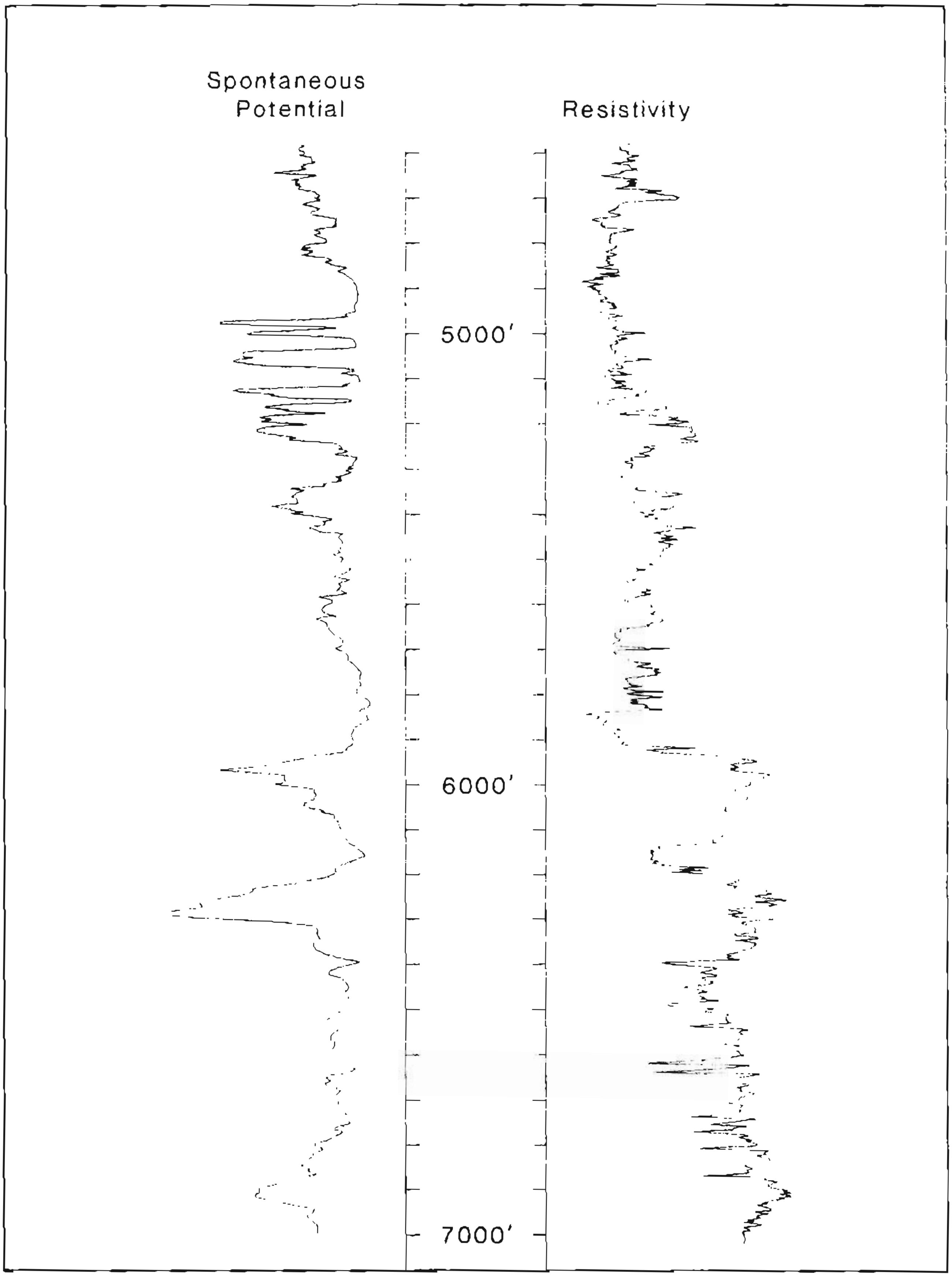

Figure 2. Well log

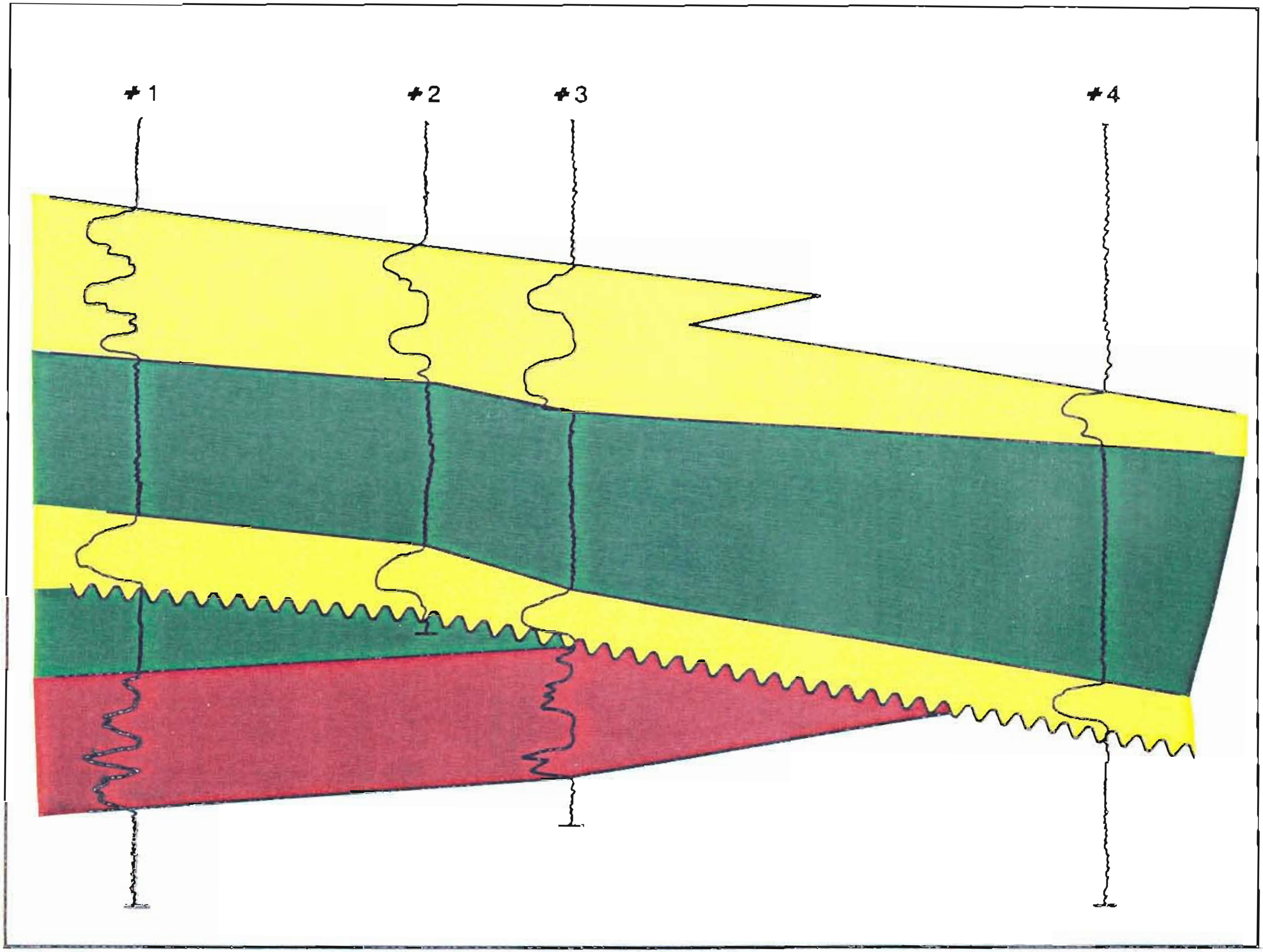

Figure 3. Geologic cross-section

GEOPHYSICAL SURVEYS

Geophysical surveys can be divided into two types -- potential field methods and seismic methods. The most commonly used potential field methods are gravity and magnetic measurements. These are generally used in order to determine whether or not a basin exists in an area, and the geometry of a basin.

The gravity survey uses a gravimeter to measure the gravity "pull" at various stations. Sedimentary rocks have less density than the basement rocks which underly them. So, thicker layers of sedimentary rocks create a smaller "pull", while thin sediments ments over the more dense basement rocks yield a greater "pull" (Fig. 4). Interpreting these measurements taken at stations throughout the area will eventually yield a configuration of the basement rocks, and thus, the geometry of the basin.

Magnetic surveys are based on the concept that most sedimentary rocks are nearly nonmagnetic, but the underlying basement rocks are slightly magnetic. Therefore, just as differing thicknesses of sedimentary rocks cause variations in the "pull" of gravity, so will they cause variations in the magnetic field, allowing one to determine the gross structure of the basin.

Gravity and magnetic surveys are inexpensive exploration methods and several important oil fields in the lower 48 have been discovered using these methods. However, a detailed investigation of an area is best accomplished by gathering data using seismic techniques; we will be concerned only with the seismic reflection method.

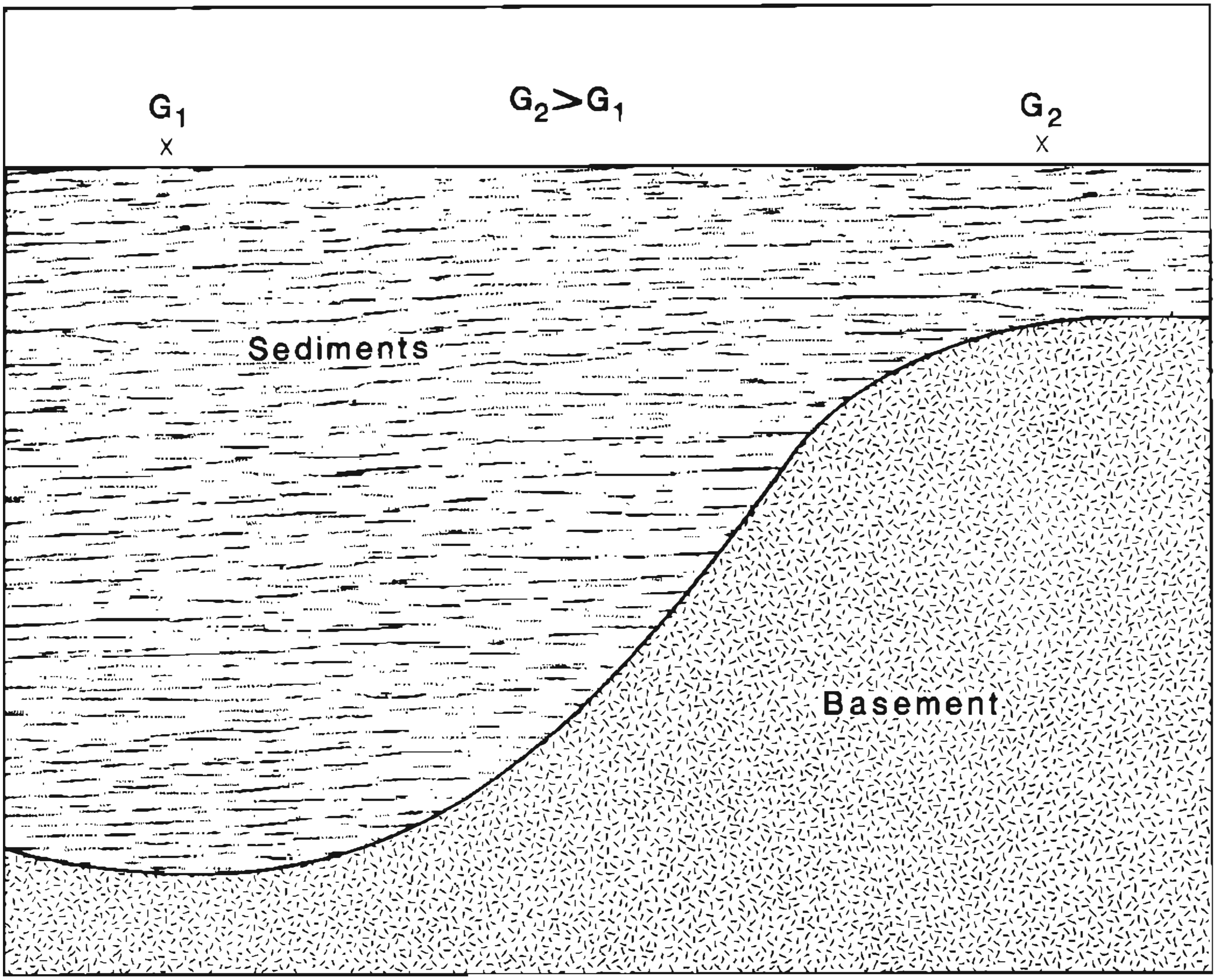

Figure 4. Comparison of gravity values (G)

SEISMIC REFLECTION THEORY

The seismic reflection method utilizes an energy source that causes energy waves to travel into the earth which are reflected back to the surface. The energy sources on land and ice range from dynamite to Vibroseis (in which a heavy truck is lifted up on a plate that is then vibrated through a prescribed frequency range). In water there are several sources, the most popular of which is the air gun, in which highly compressed air is released from a "gun" into the water. The resultant shock wave then travels into the rock layers beneath the water.

As the energy travels into the earth it encounters rock layers of varying properties. At these interfaces a small portion of the energy is reflected back to the surface and recorded by sensitive instruments called geophones (on land) or hydrophones (in water) (Fig. 5). The energy recorded by these instruments then undergoes computer processing; the result is a seismic profile (Fig. 6). This profile can be looked upon as a cutaway of the earth measured in two-way time (i.e. the time it takes energy to travel into the earth and be reflected back to the surface). Each time line on the profile indicates the number of seconds it takes for the energy to travel to that depth and back to the surface. Different formations show up as black bands (called horizons) running laterally across the seismic profile.

It is the job of the geophysicists to interpret this seismic profile. They do this by transferring information from well logs onto the seismic profile and then tracing the horizons of interest (see Fig. 7). This profile shows four interpreted horizons, with the faults drawn in. The two large faulted anticlines could be excellent trapping mechanisms for hydrocarbons.

To match up the formations to be mapped with the correct horizons on the seismic profile it is essential that some of the seismic lines in an area connect with existing wells. The geophysicists must transfer the geologist's "picks" of the formation tops from the well log onto the seismic profile. However, the well logs are measured in depth and the seismic profile in time. To accomplish this transfer the geophysicists use a synthetic seismogram, which is an artificial seismic reflection record made from velocity and density logs (Fig. 8). Time and depth values have been correlated on the synthetic seismogram so the geophysicists can readily match up the formation "picks" with the seismic reflectors (horizons). The geophysicists then place the synthetic onto the seismic profile at the well location, match the horizons in both, then transfer the "picks" onto the seismic profile. Once this is done each horizon is carried from profile to profile throughout the area.

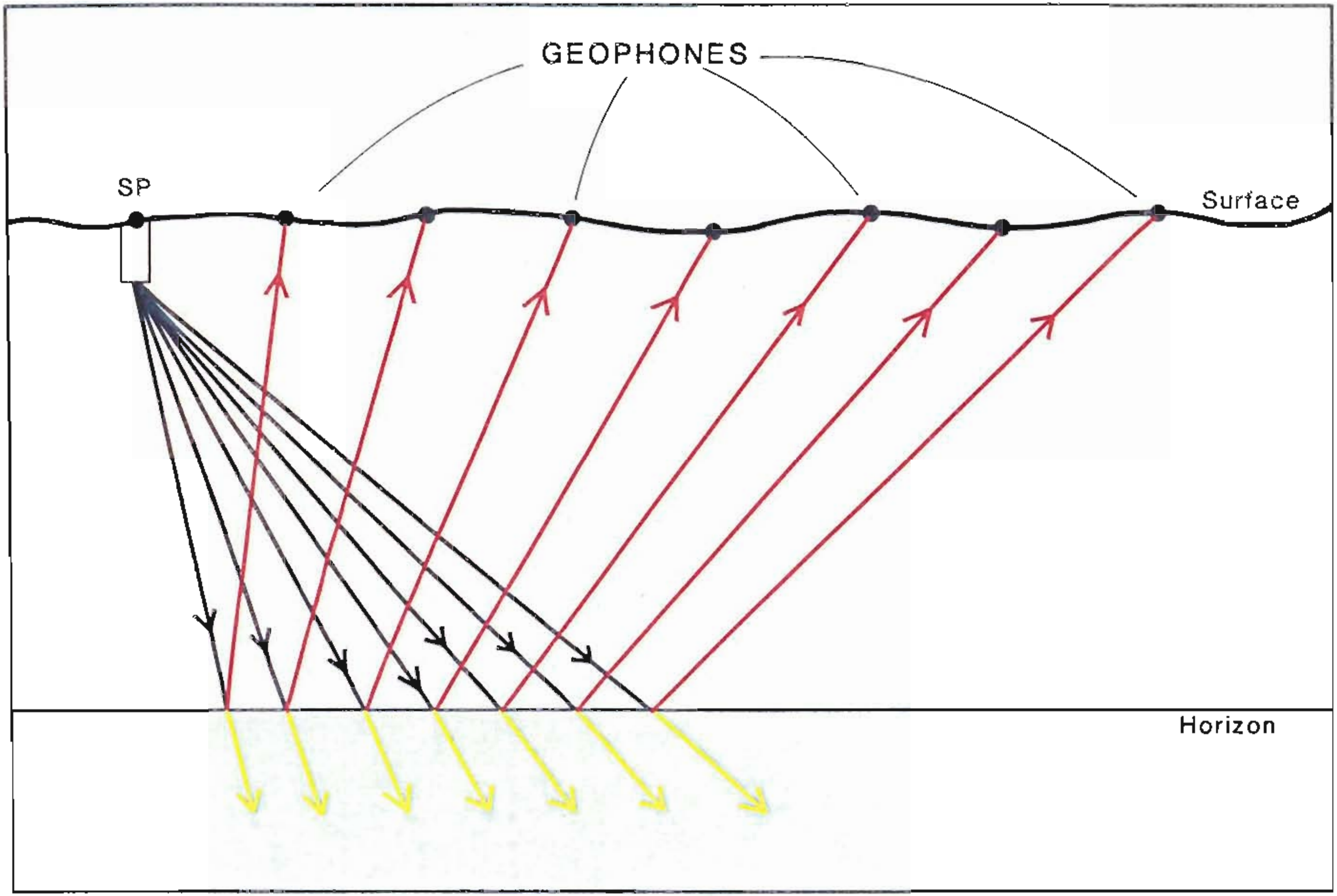

Figure 5. Seismic reflection method

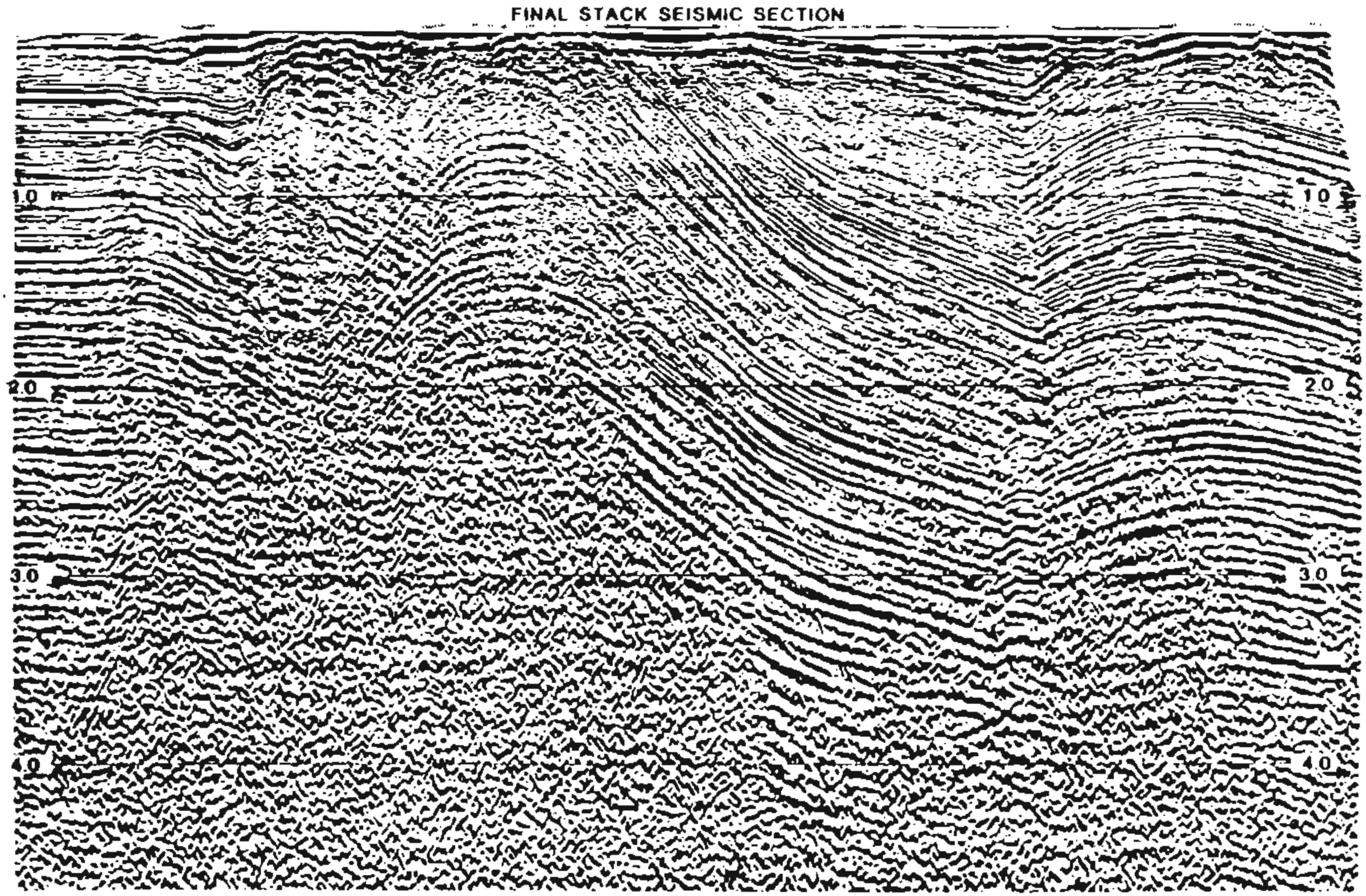

Figure 6. Seismic Profile

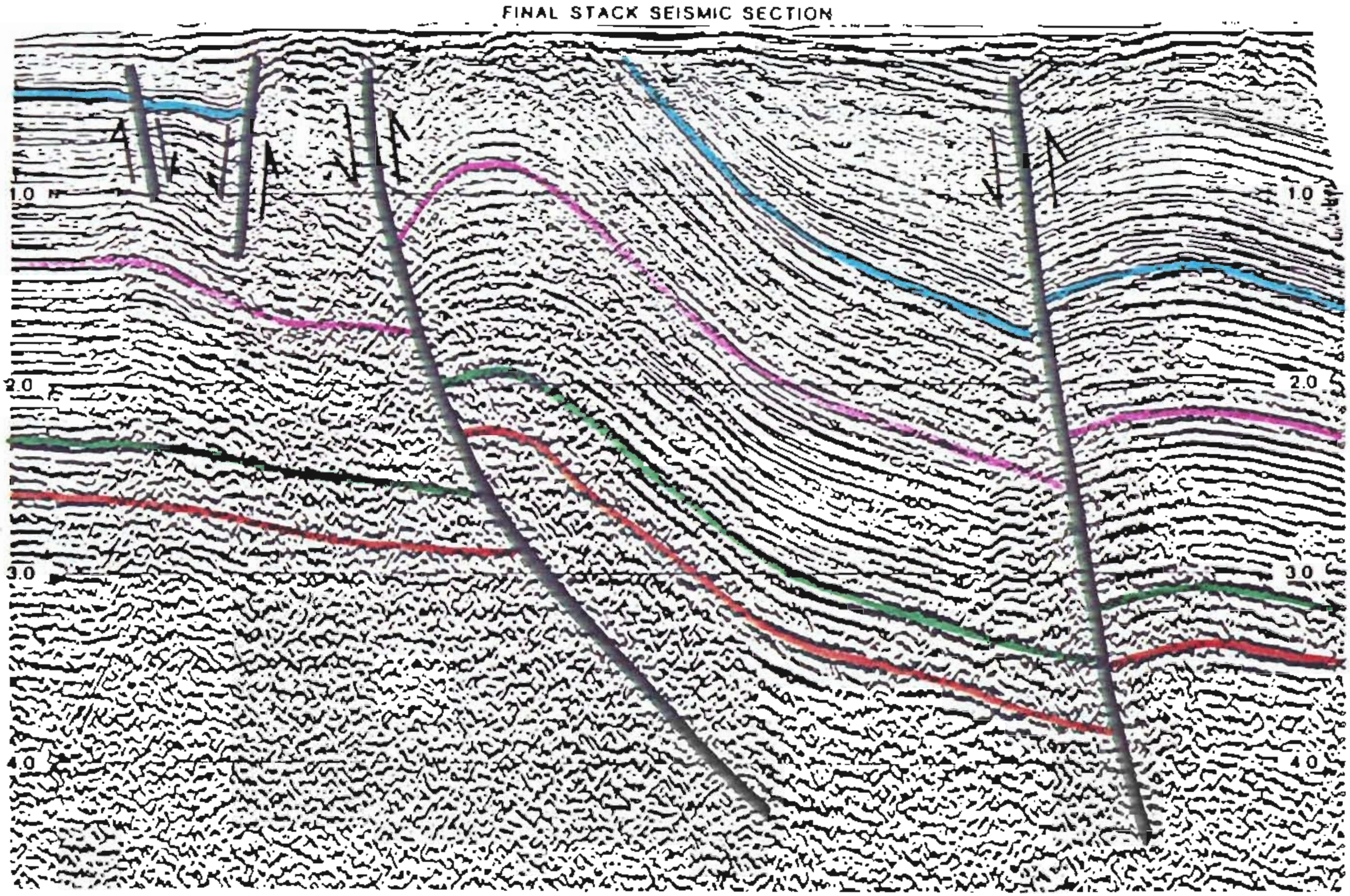

Figure 7. Interpreted Seismic Data

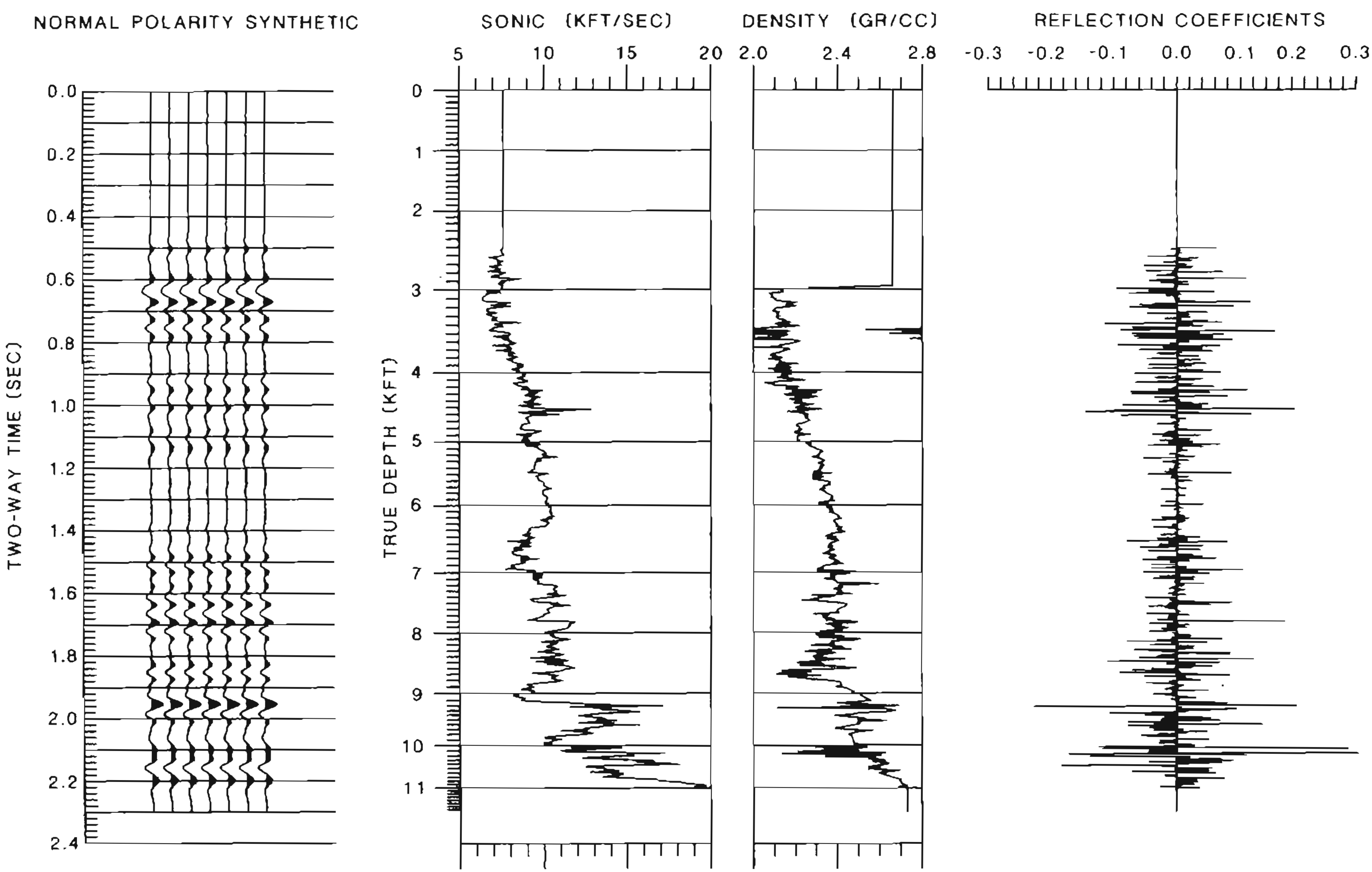

Figure 8. Synthetic Seismogram

PRE-SALE EVALUATION

Once an area is on the State's five-year oil and gas lease sale schedule DGGS conducts geological field studies and gravity and magnetic studies as required. If seismic surveys have been conducted within the area by oil companies and seismic service companies, DGGS will acquire the data necessary to complete a detailed evaluation. Data gathered on unleased State lands are, by regulation, turned over to the State as a condition of the permit. Data beyond the three mile limit can be acquired from the Minerals Management Service (MMS) of the Dept. of the Interior or can be purchased from the owners of the data. Also, data collected on unleased State lands prior to March, 1981 (the effective date of the regulations requiring companies to submit their data) may be purchased from the owners of the data at their discretion.

Figure 9 shows the outline of a sample lease sale area, with the seismic lines and wells indicated. As already stated, seismic surveys will attempt to connect the seismic lines to as many wells as possible since wells offer the most accurate means of obtaining subsurface information. The three well locations below the sale area indicated by black dots repesent producing oil wells.

Once the geophysicists have interpreted all the seismic profiles they then create time maps of the area, i.e. maps of each subsurface horizon in two-way time (as shown on the seismic profile), much like a topographic map. When they are satisfied with the accuracy of the time values, and of the velocity data from the seismic surveys (the changing velocity of the energy as it travels through the different rock layers) the two are combined to yield depth values ($D = VT$).

Figure 10 is the resultant depth map of horizon "B" (magenta) on the seimic profile. The major faults are shown by the heavy black lines, the magenta areas are hydrocarbon traps (faulted anticlines and a stratigraphic trap) called "prospects", the green area shows the existing oil field, and the red outline shows the limit of production (i.e. the oil/water contact), projected into the sale area. The truncation line running along the top of the map indicates where Horizon "B" is cut off by an overlying bed (the top of the horizon does not exist beyond this line), and the blue line locates the seismic profile from Figure 6. This map shows eight separate prospects, one of which is in a drainage situation adjacent to the existing production.

This seismic depth map can be compared with a map (Fig. 11) of the same area derived from subsurface well information only. In a frontier area where there are no wells the geologists must project their interpretation from existing wells as far as possible into the unmapped region. This map, obviously, is far less informative than the seismic depth map. Only two prospects can be identified, and they do not resemble the same prospects as mapped from seismic data. Most important, the extent of the oil/water contact around the producing field is greatly reduced. The dashed lines indicate the lack of data control points; the geologist can only make an educated guess as to how the contours are drawn or whether the fault exists as shown

A geologic map of this area can only define trends, but the economic analysis by DO&G that calculates the projected revenue under different bidding methods requires figures derived from analyzing prospects in the sale area. Once the prospects have been located they are re-mapped at a smaller contour interval in order to better delineate the different fill levels. Figure 12 shows Prospect #1, (located in the center of the seismic profile) and the individual tracts associated with it. This is considered a wildcat prospect, since it is based solely on seismic information. To analyze it the geophysicists determine the 100% and 50% (red countour) fill levels, since there is no guarantee that the prospect is completely filled with oil. Then the acreage for each fill level for the entire prospect and then for each individual tract is measured.

The simplified formula that is used to calculate the barrels of oil present in the prospect is:

[Acres][Formation Thickness][Oil Recovery Factor] = Barrels of Oil

[Ac] [Ft] [BBL/Ac-Ft] = BBL

The thickness of the reservoir rock is derived from the well logs and the recovery factor encompasses a variety of parameters and calculations, including known rate of production from this particular formation in nearby areas, or production from this type of rock in other areas if there is no production nearby, the gas oil ratio (GOR), etc. This is where the work of the geologist comes into fruition; the determination of the porosity, the estimated permeability, the relationship of the rock types, etc. -- all are used in calculating the oil recovery factor. A sample calculation at the 100% fill level of prospect #1, using figures from the Sadlerochit formation is as follows:

[5000 Acres] [125 Ft] [300 BBL/Ac-Ft] = 187,500,000 BBL(unrisked)

This figure assumes that the prospect contains hydrocarbons. Until it is drilled there is no way of knowing whether this is true. The evaulation team must now do a risk analysis of this prospect. Using knowledge of the area a Basin Risk is assigned (max of 1.0), i.e. the probability that pooled and recoverable hydrocarbons exist somewhere within the sale area. Then the confidence in geologic parameters is assigned a risk factor (max of 1.0). This risk factor is based on the proximity to known accumulations, distance to well control and the understanding of the area geology. Confidence in the trapping mechanism is also assigned a risk factor (max of 1.0), and is based on the quality of the seismic data (how easy it is to interpret the seismic profiles) and on the complexity of the trapping mechanism. Following is the formula for the Success Factor of this prospect, along with some sample calculations:

[Basin Risk][Confidence - Geol.][Confidence - Trap] = Success Factor
[Parameters] [Mechanism]

[1.0] [0.20] [0.20] = 0.04 = 4%

Stated another way, there is a dry hole risk of 96%. This Success Factor is multiplied times the calculated unrisked BBL to yield the risked value of 7,500,000 BBL.

For prospect #2, adjacent to the known production, the risks will be less, but will still be present. In this prospect (Fig. 13) the oil water contact from the producing field is extended into the sale area. However, it is not certain that the oil is trapped in the structure shown, or that the rock properties of the formation remain the same towards the north. So, there will be risk factors assigned, just as with Prospect #1, however the Success Factor would be higher.

These calculations are actually ranged between Minimum, Most Likely, and Maximum, and are made for each fill level for the entire prospect, and then for each tract involved with the prosp. These figures, along with the geologic assessment of the area are discussed with the staff at DO&G so they can run their economic analysis to determine the present value of the prospect under the different bidding systems. Then all results are presented to the Commissioner of Natural Resources so that sale conditions that should maximize revenue for the State can be set (Fig. 14).

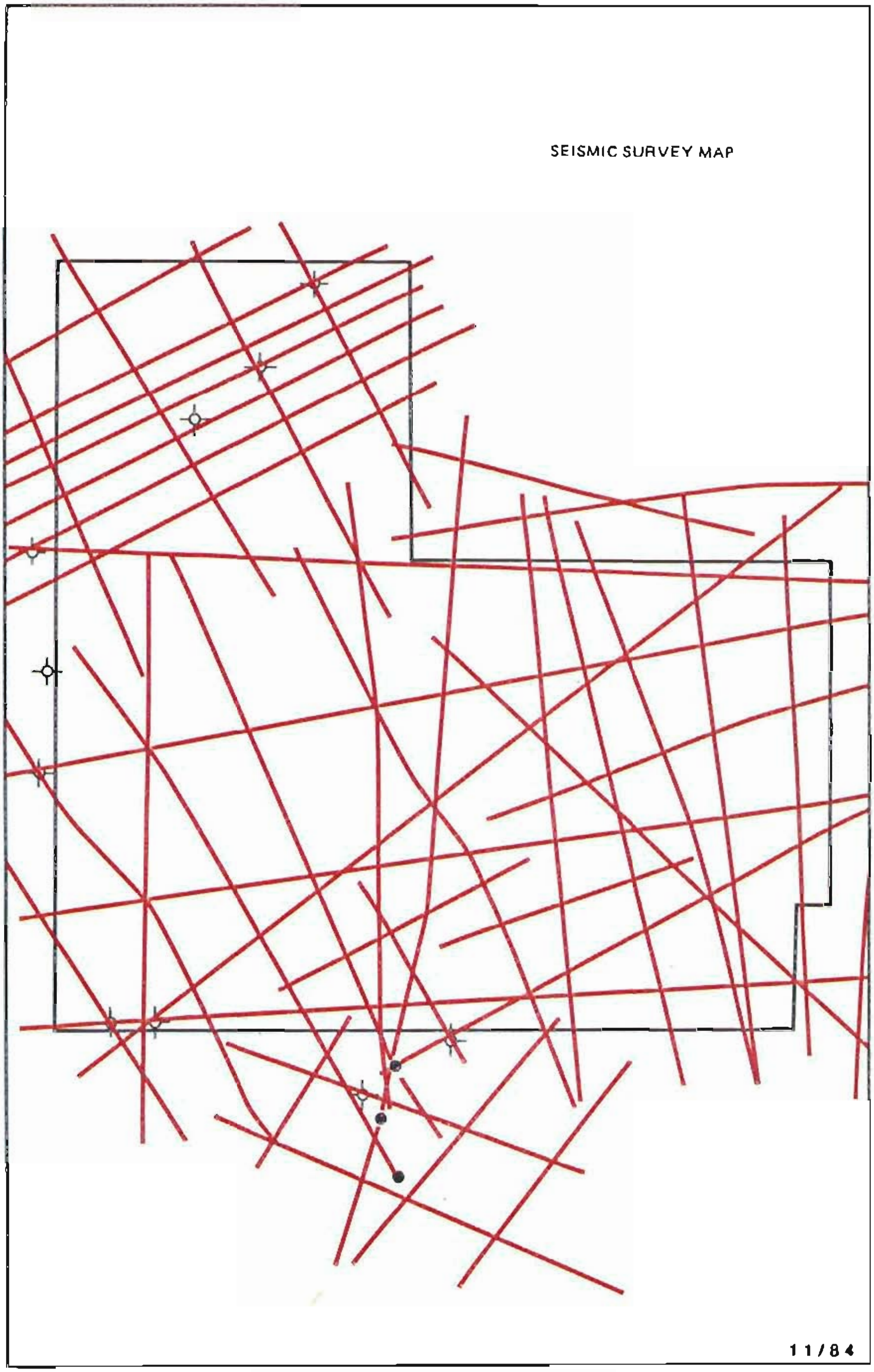

Figure 9. Seismic Survey Map

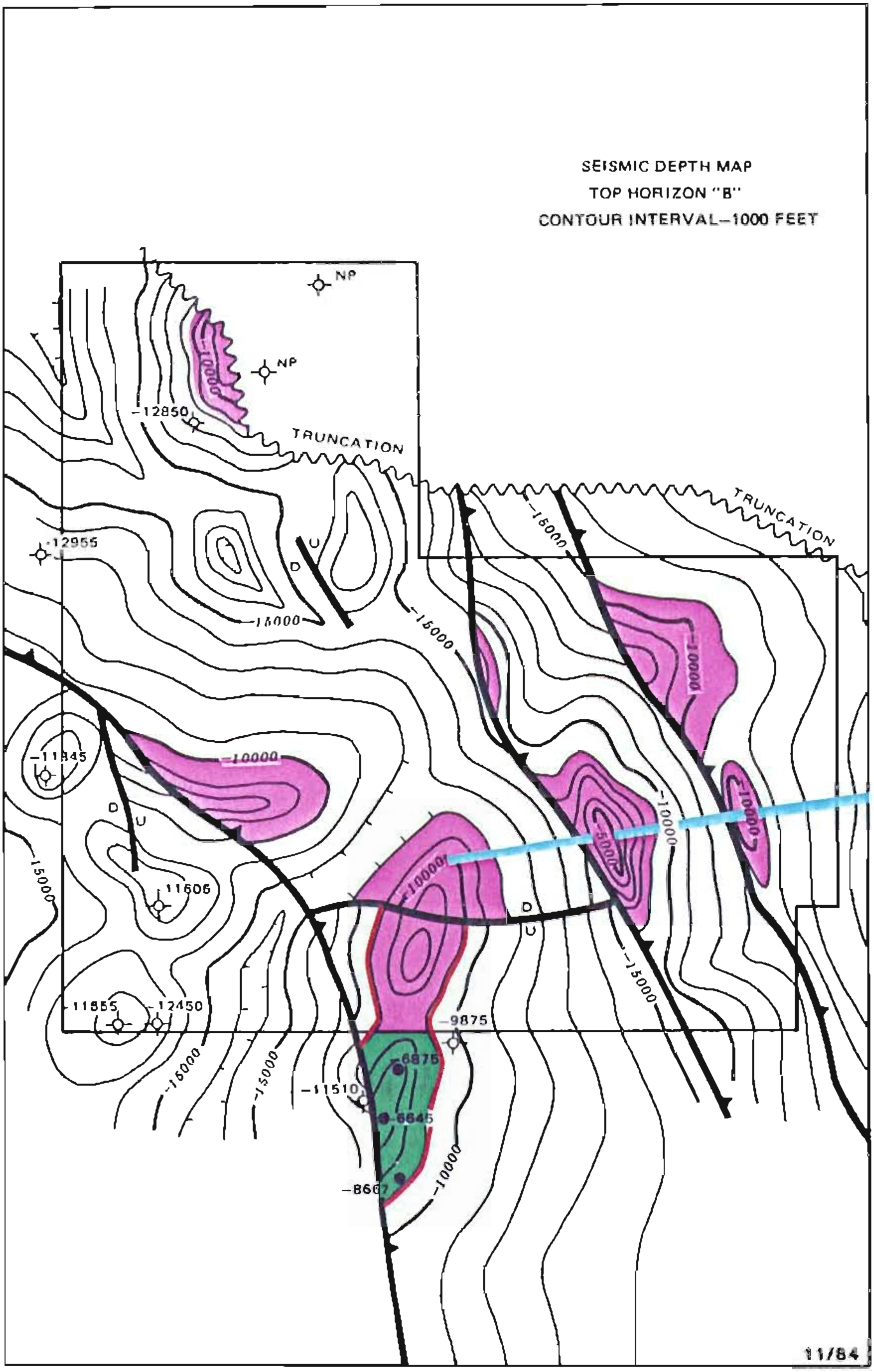

Figure 10. Seismic Depth Map

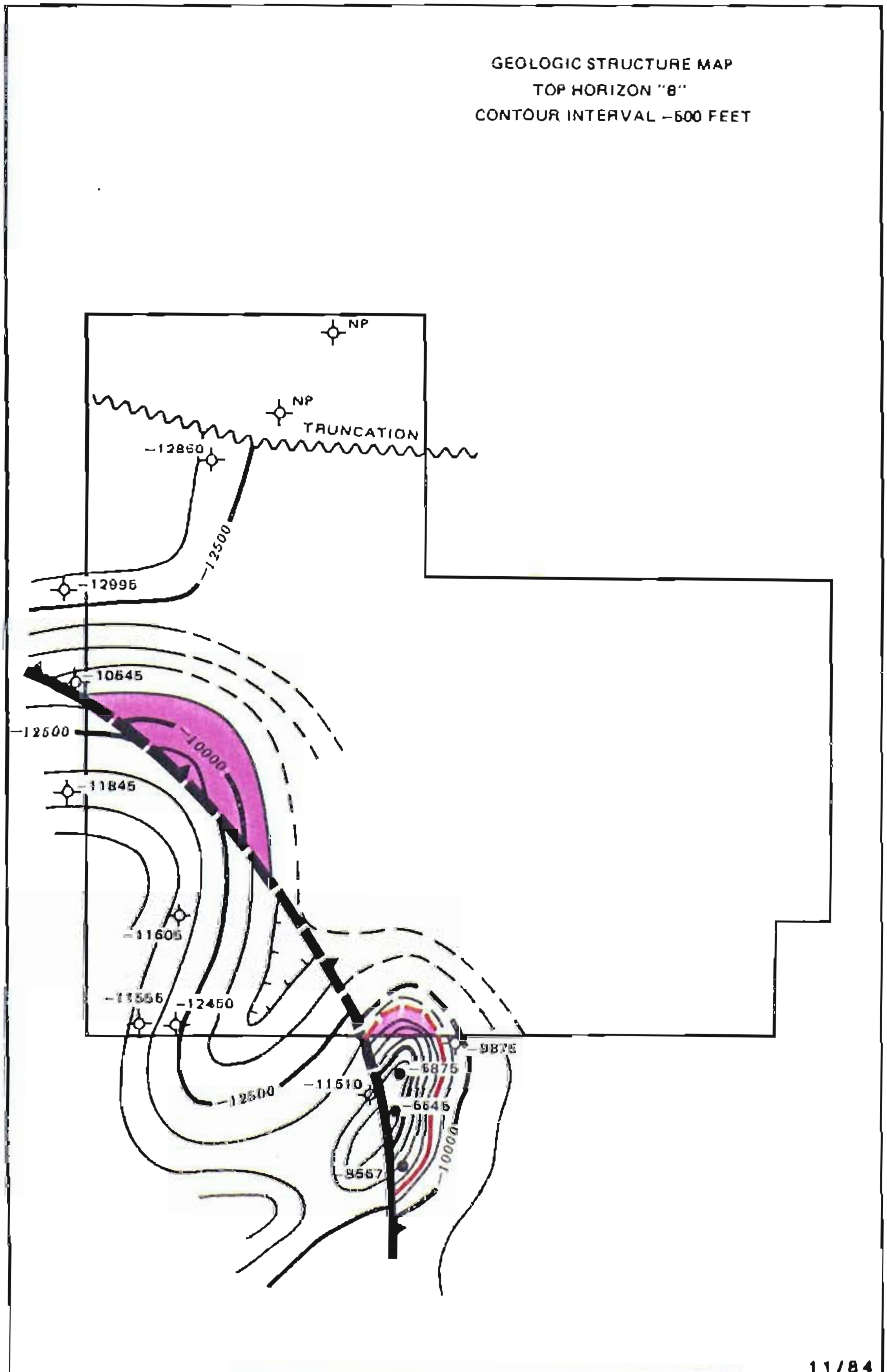

Figure 11. Geologic Structure Map

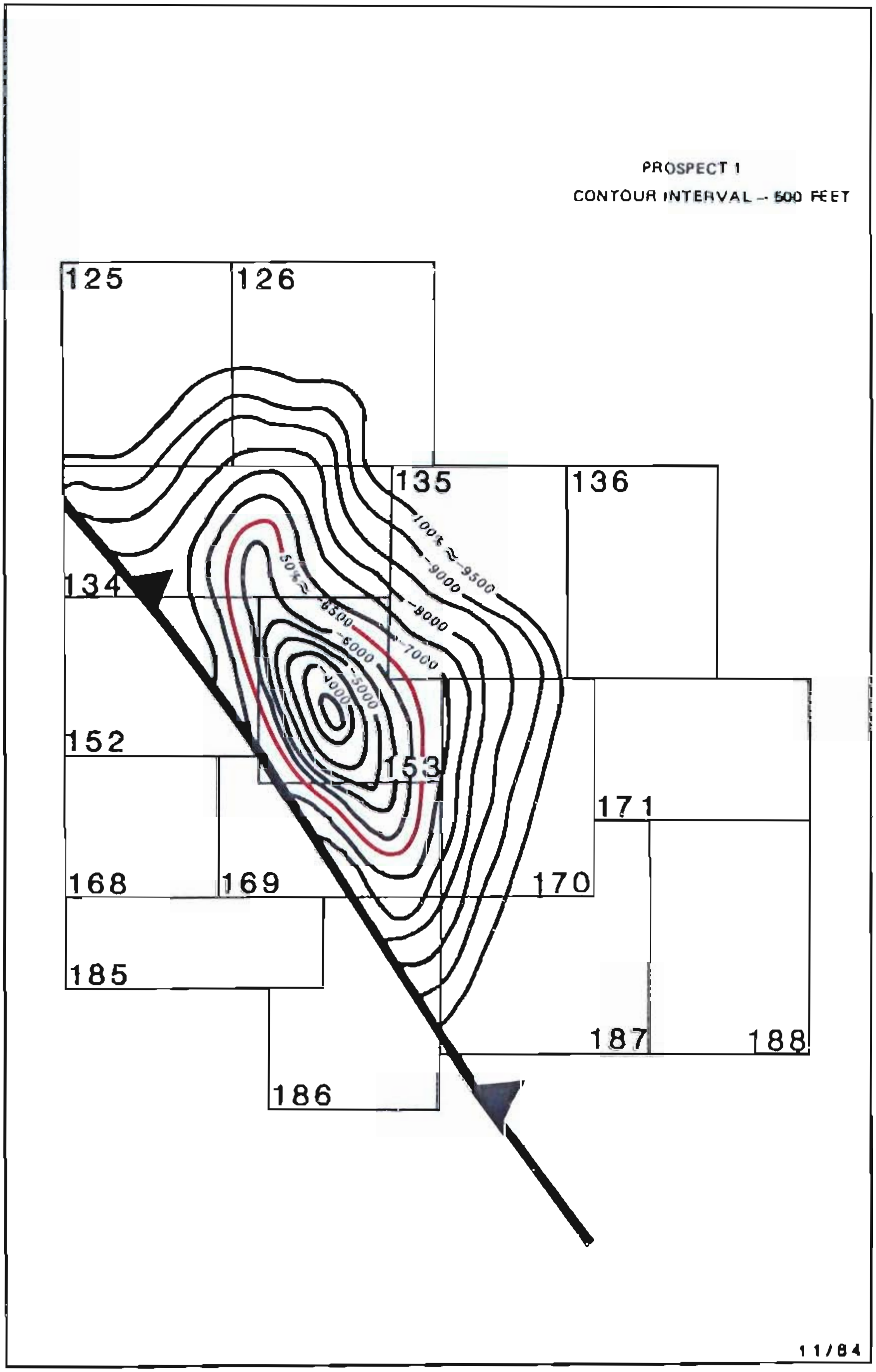

Figure 12. Prospect 1

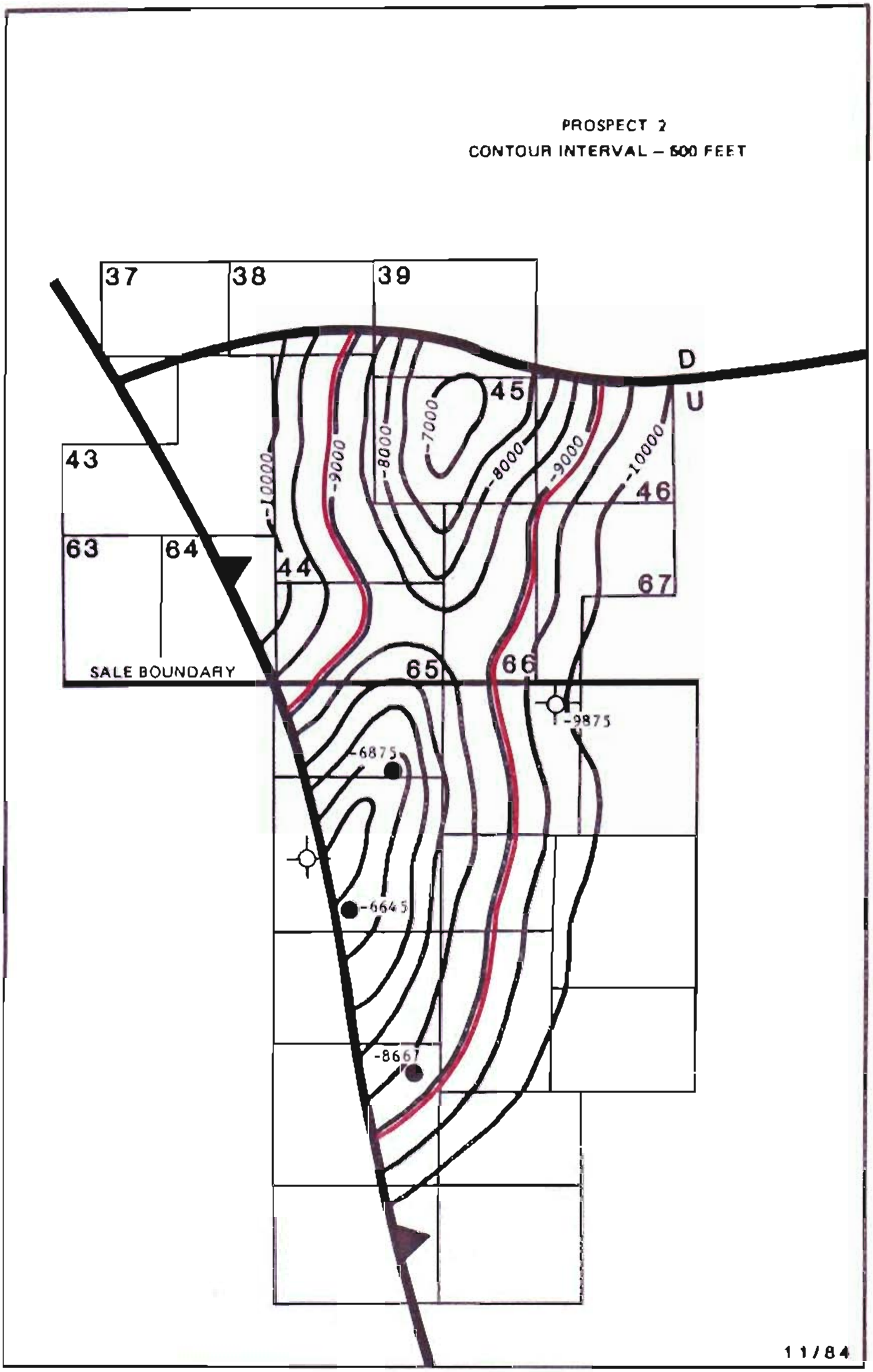

Figure 13. Prospect 2

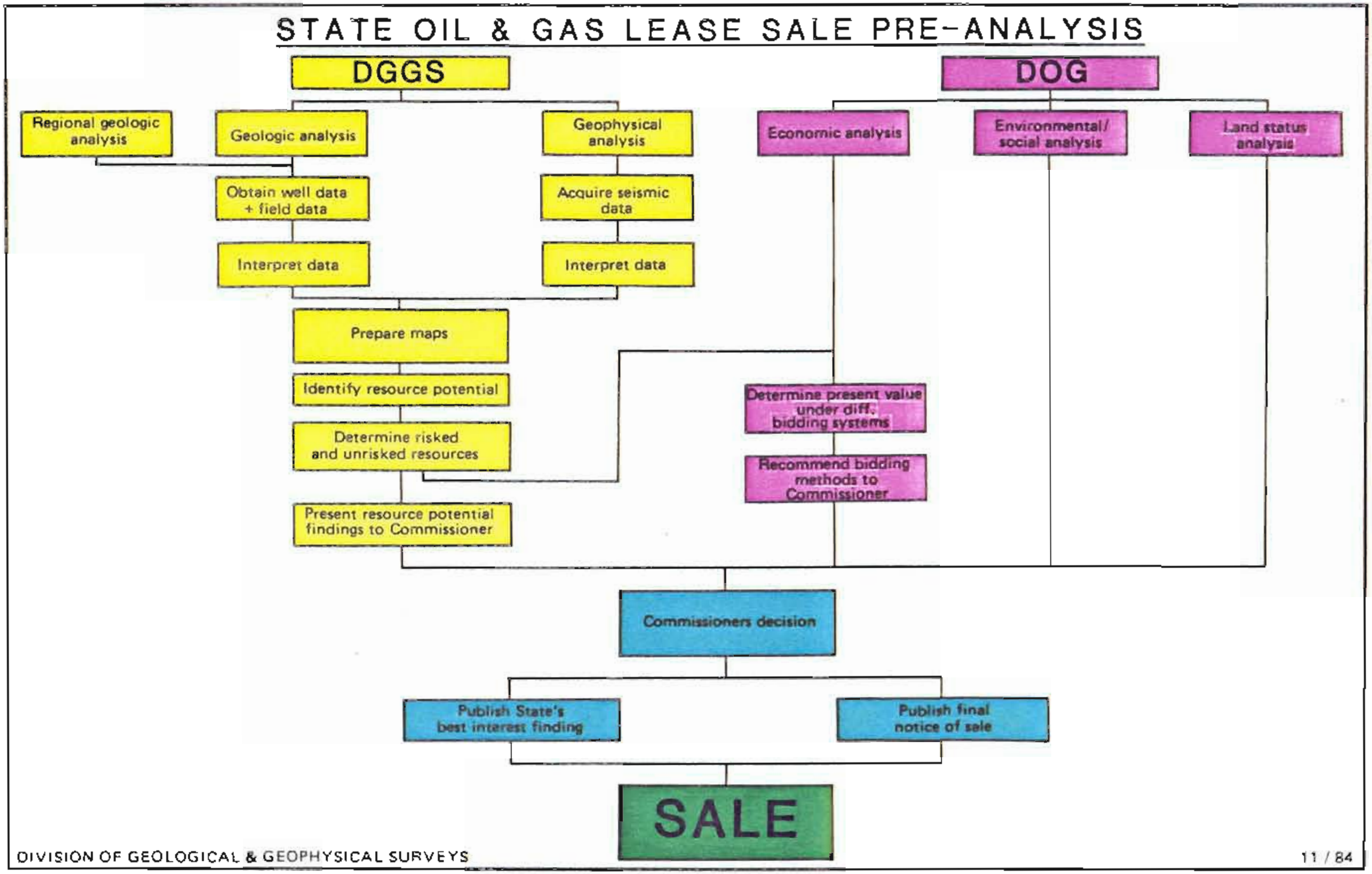
STATE OIL & GAS LEASE SALE PRE-ANALYSIS
DGGS
DOG
Regional geologic analysis
Geologic analysis
Geophysical analysis
Economic analysis
Environmental/ social analysis
Land status analysis
Obtain well data + field data
Acquire seismic data
Interpret data
Interpret data
Prepare maps
Identify resource potential
Determine risked and unrisked resources
Present resource potential findings to Commissioner
Determine present value under diff. bidding systems
Recommend bidding methods to Commissioner
Commissioners decision
Publish State's best interest finding
Publish final notice of sale
SALE
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Figure 14.