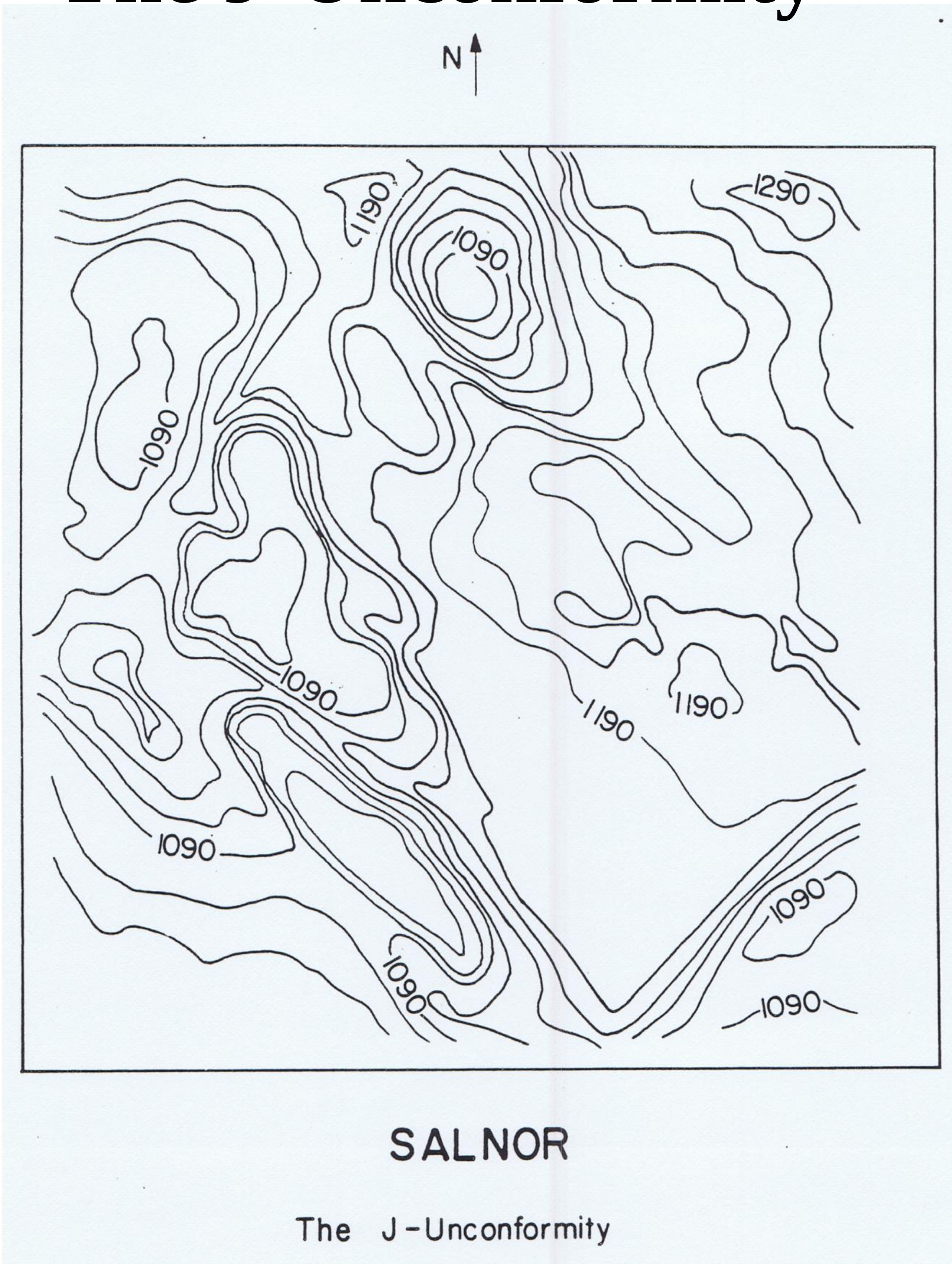
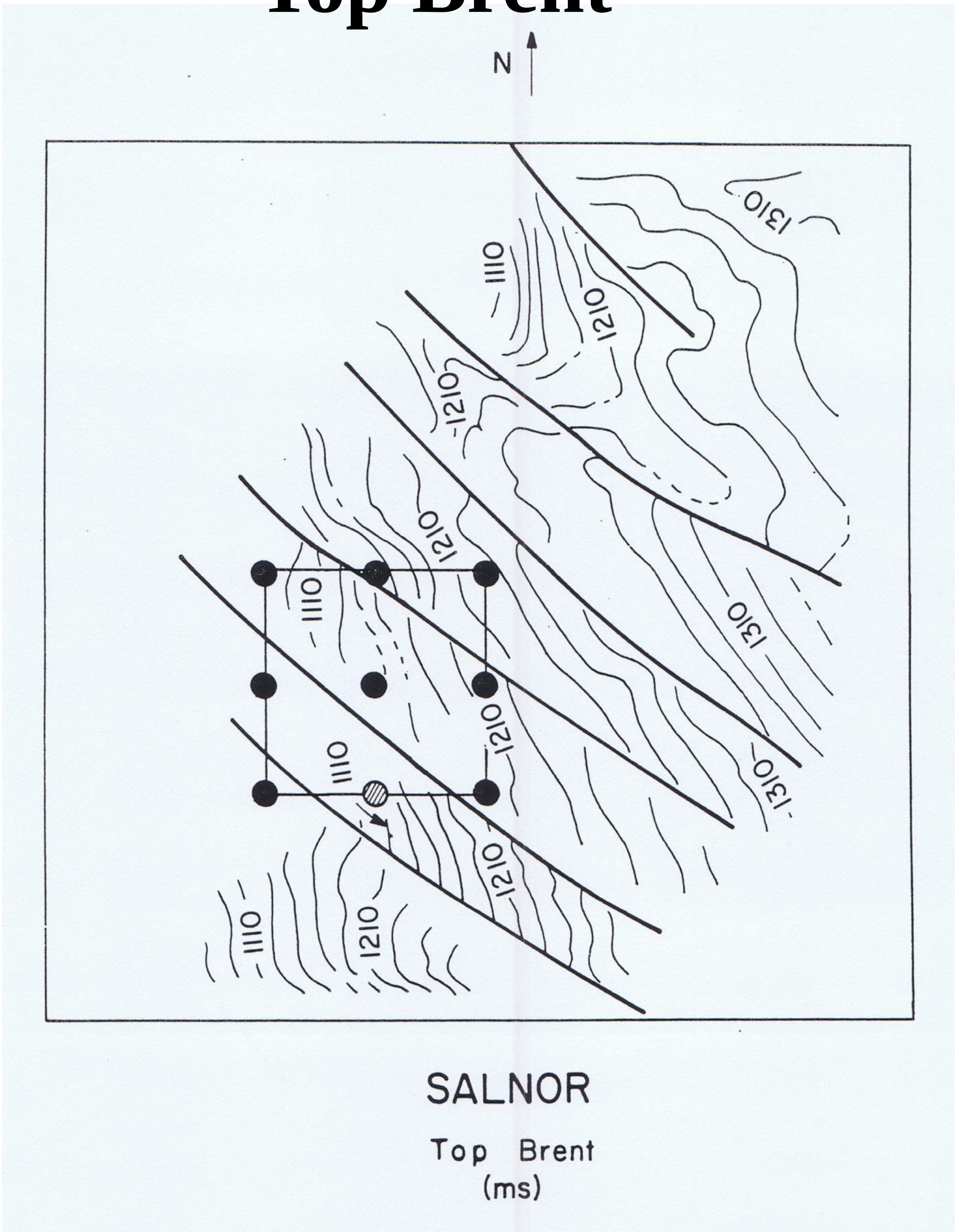
Workshop 1
Answers

H. Roice Nelson, Jr.

The J-Unconformity



Top Brent


N
1310
1110
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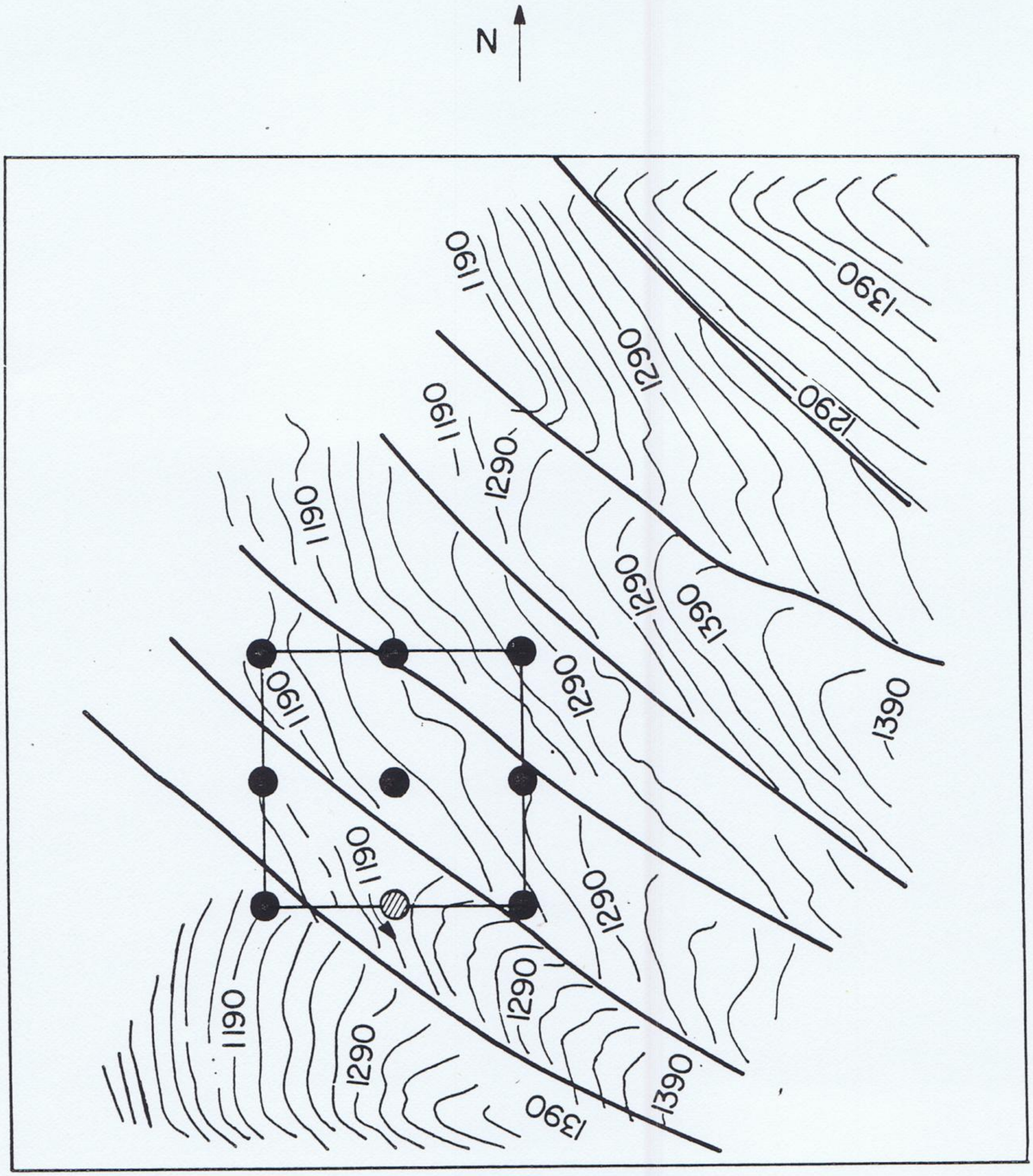
SALNOR
Top Brent
(ms)

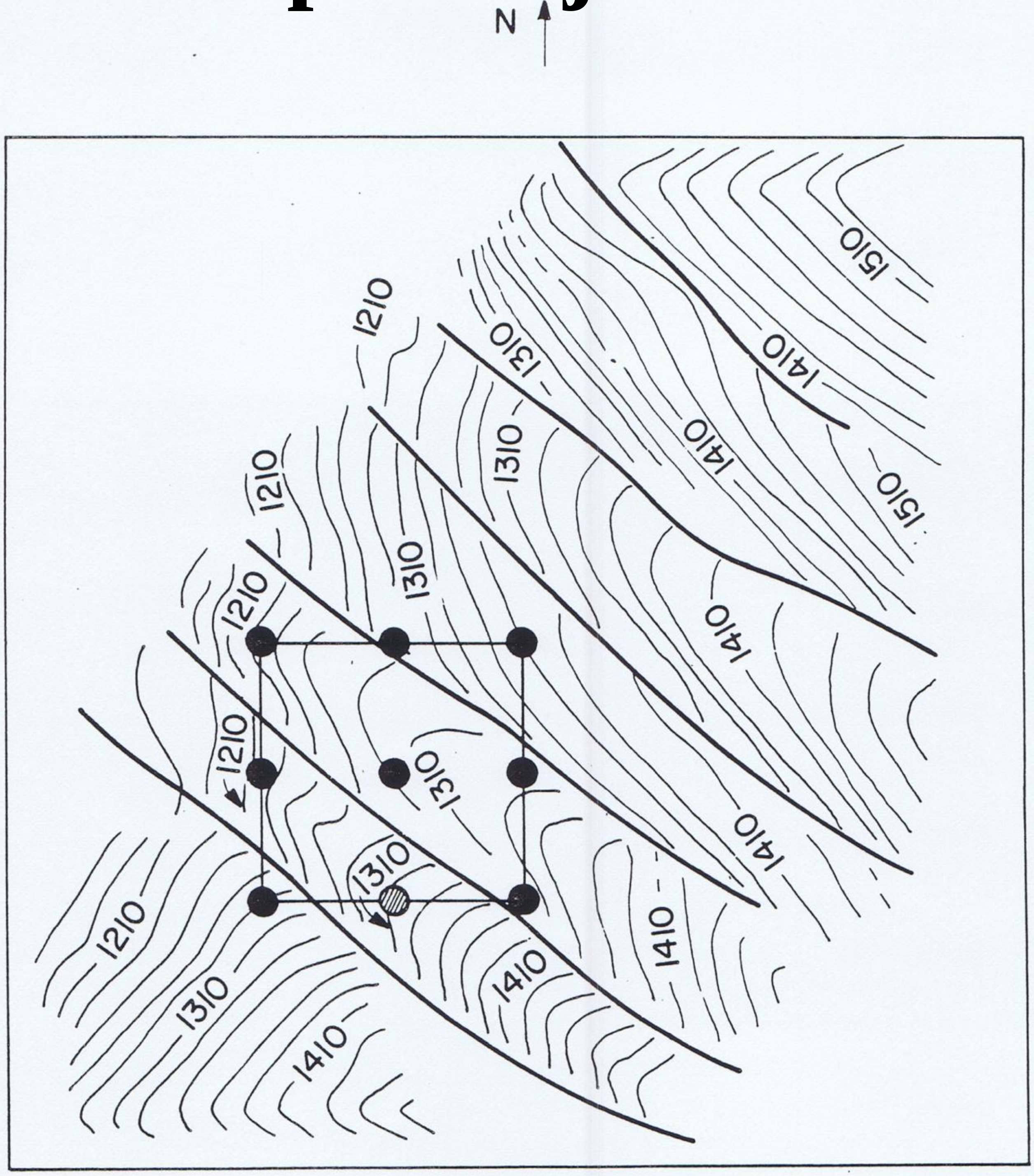
Base Brent



SALNOR

Base Brent
(ms)

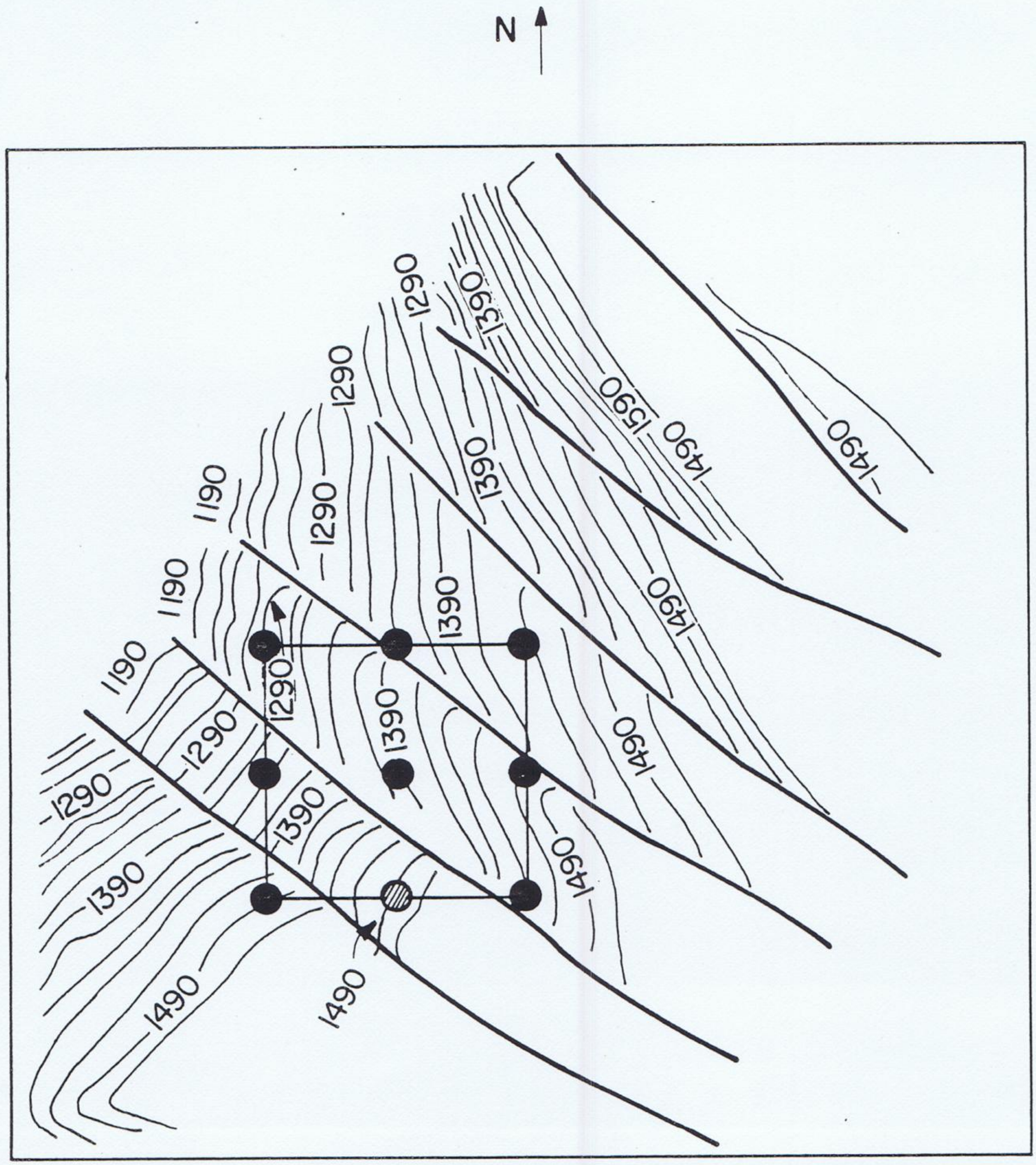
Top Statfjord



SALNOR

Top Statfjord
(ms)

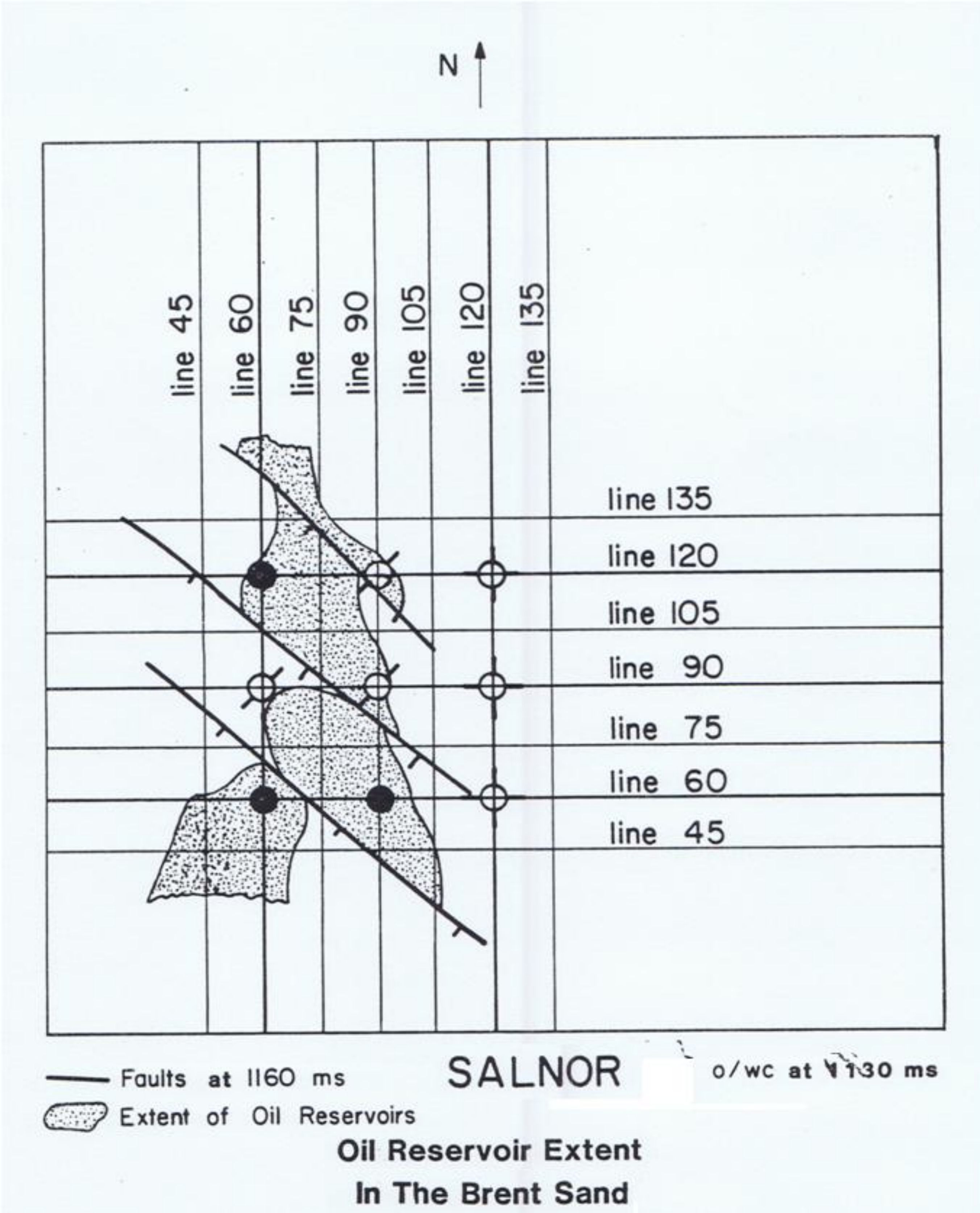
Base Statfjord



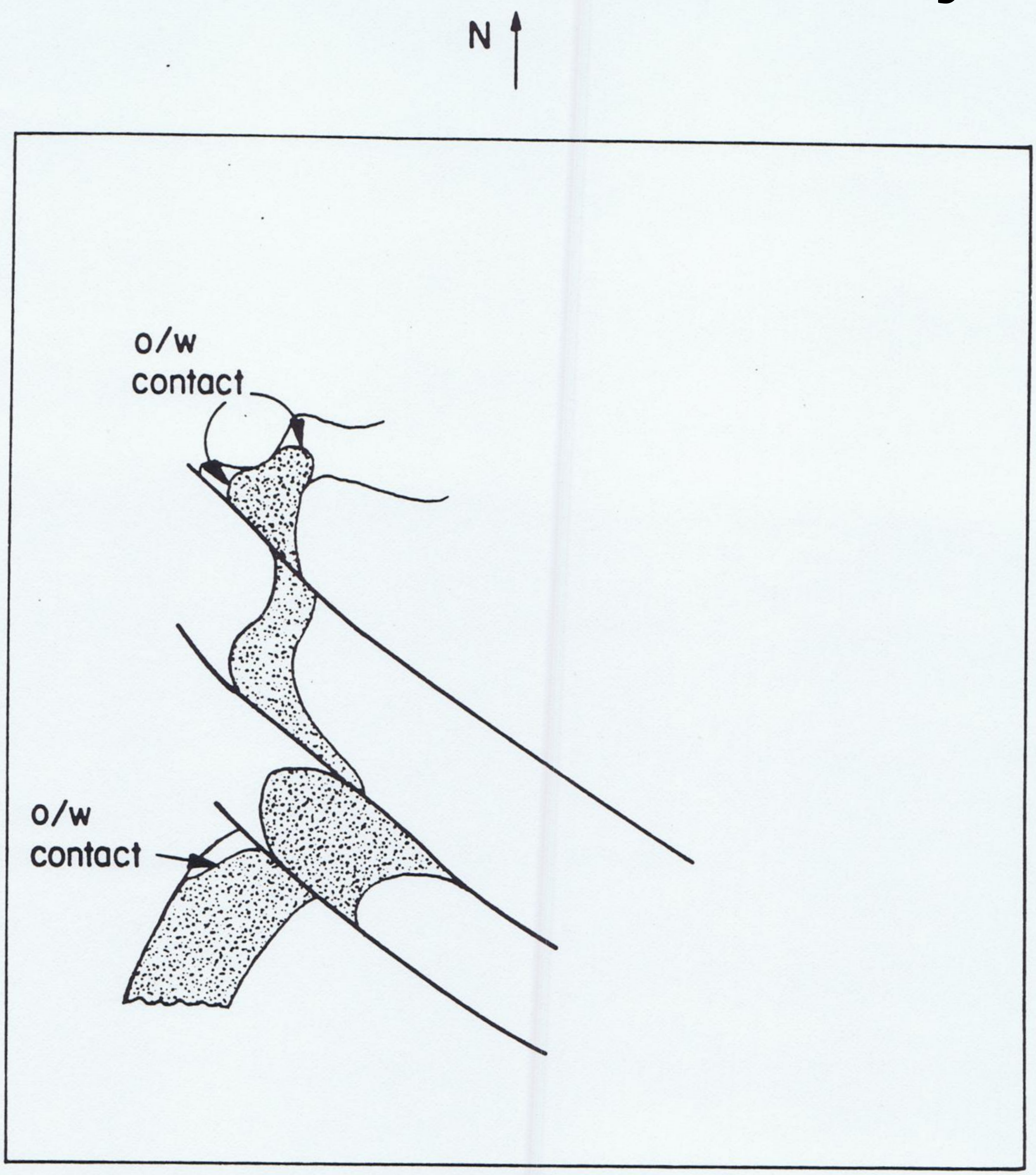
SALNOR

Base Statfjord
(ms)

Brent Oil Extent



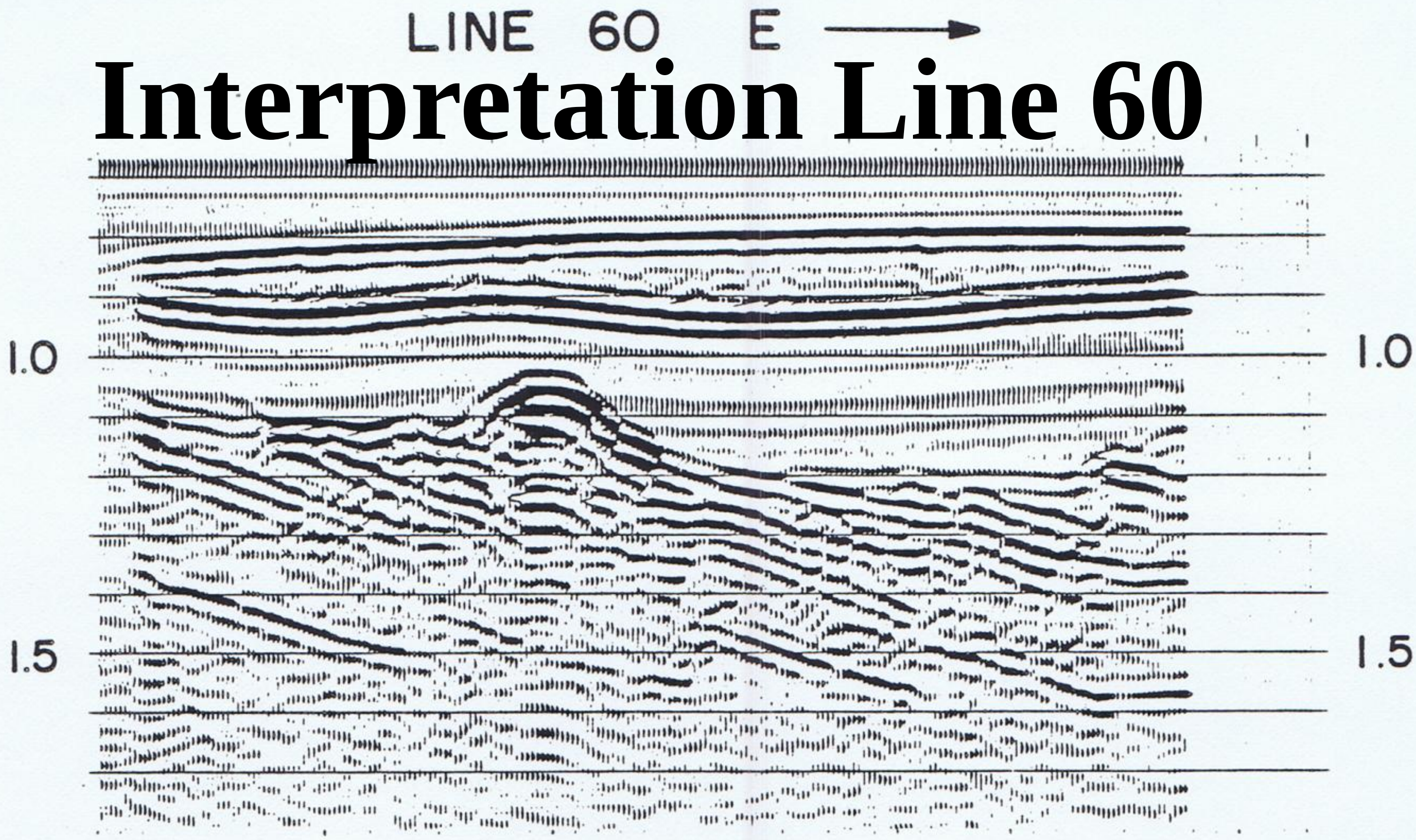
Brent & J-Unconformity



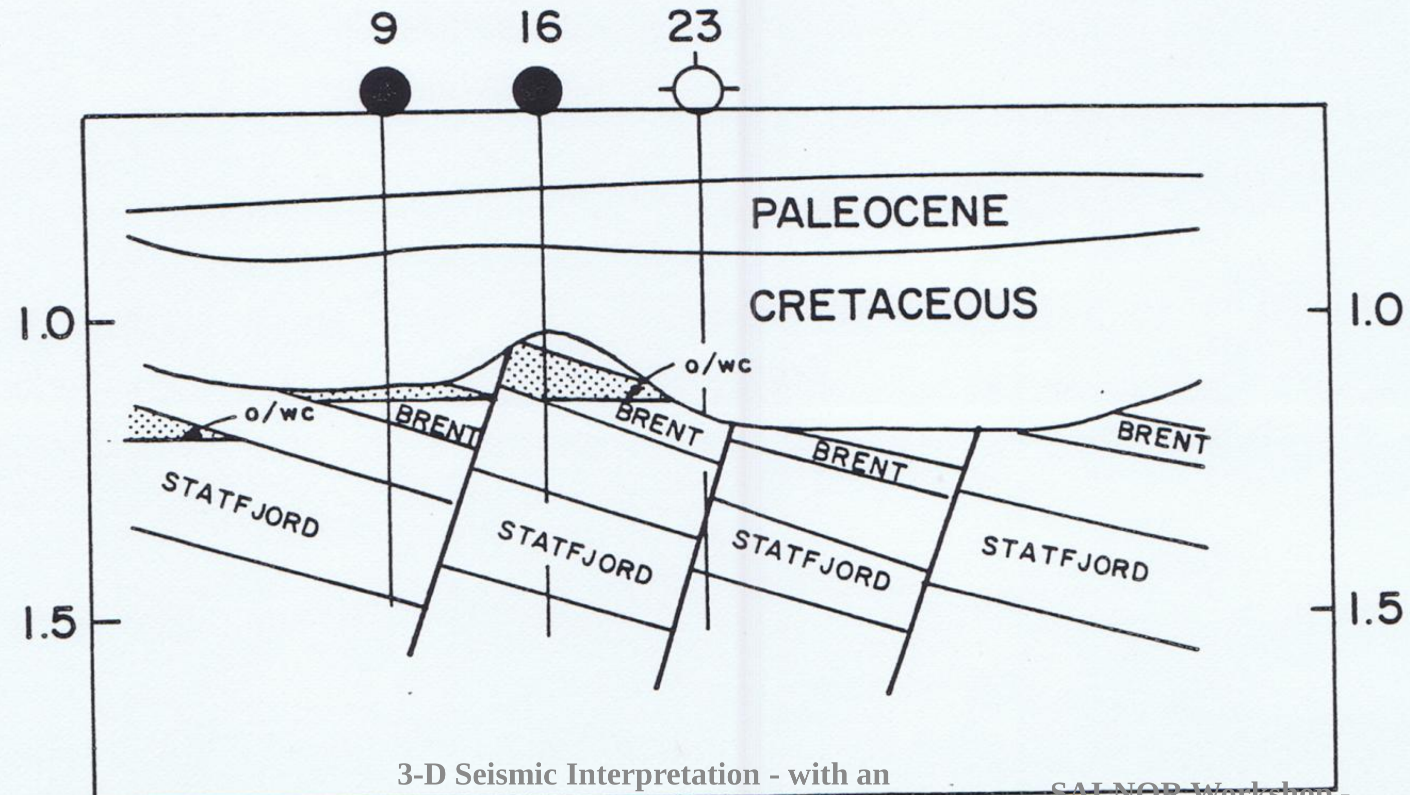
SALNOR

Contact Between Brent Sand
And The J-Unconformity

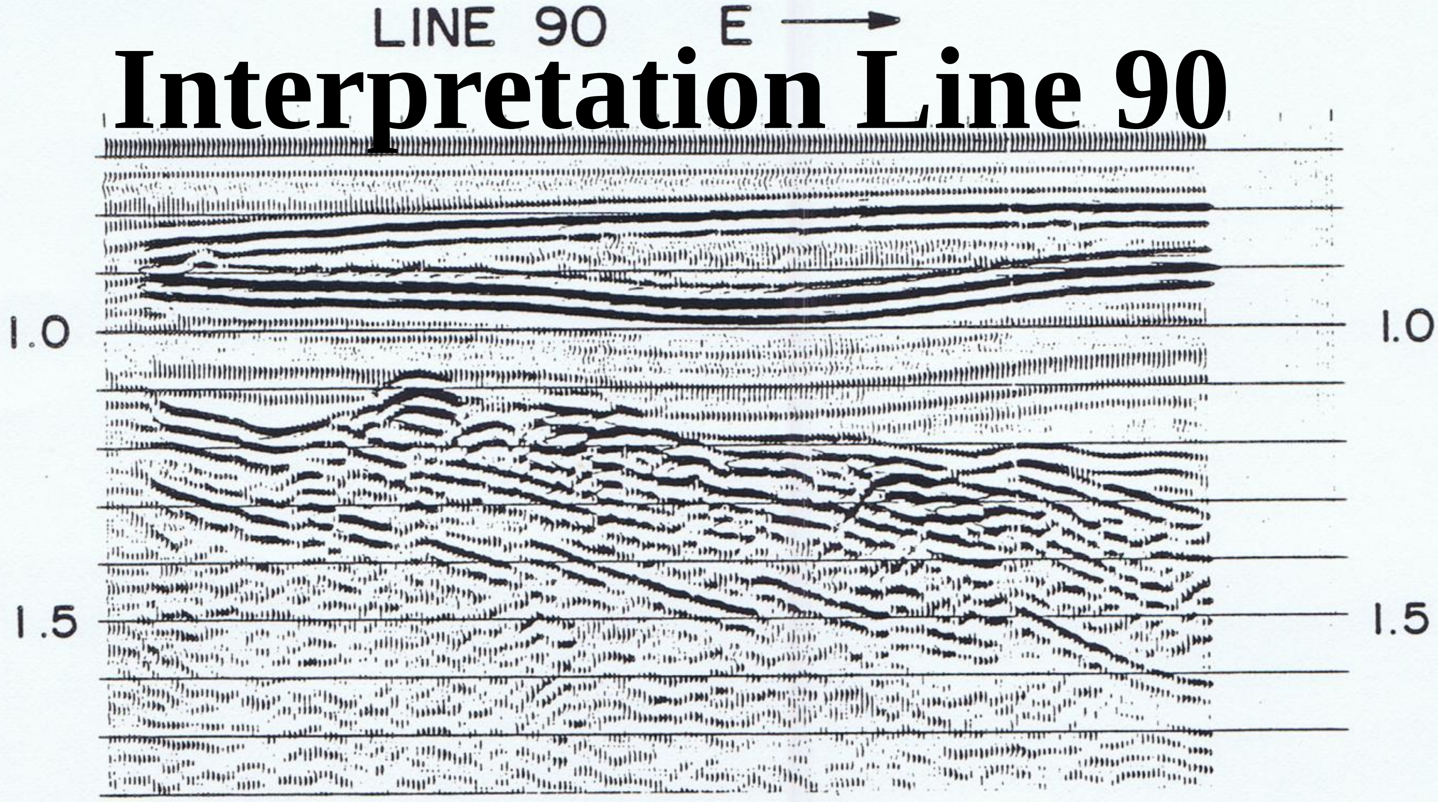
Interpretation Line 60

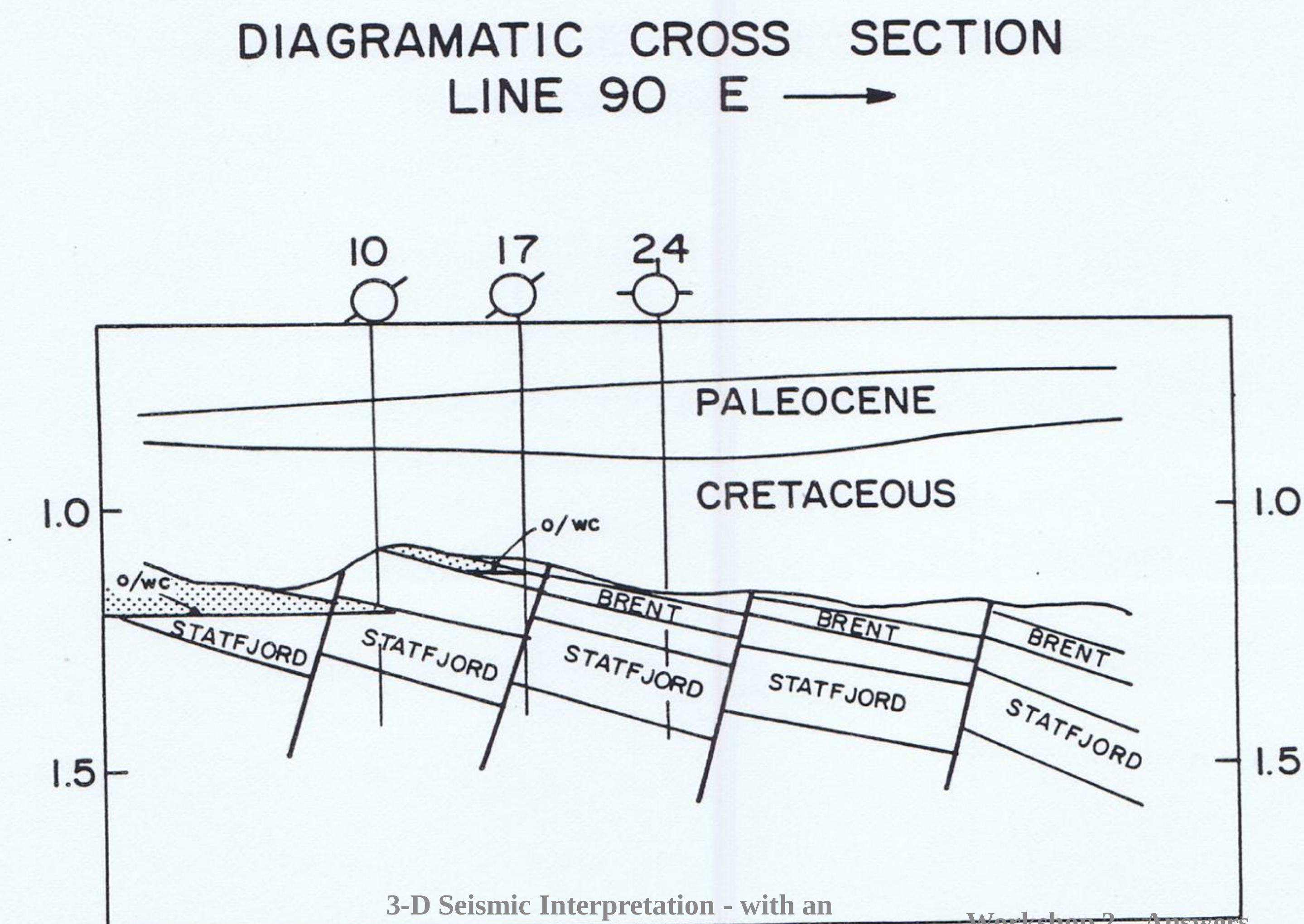


DIAGRAMATIC CROSS SECTION
LINE 60 E

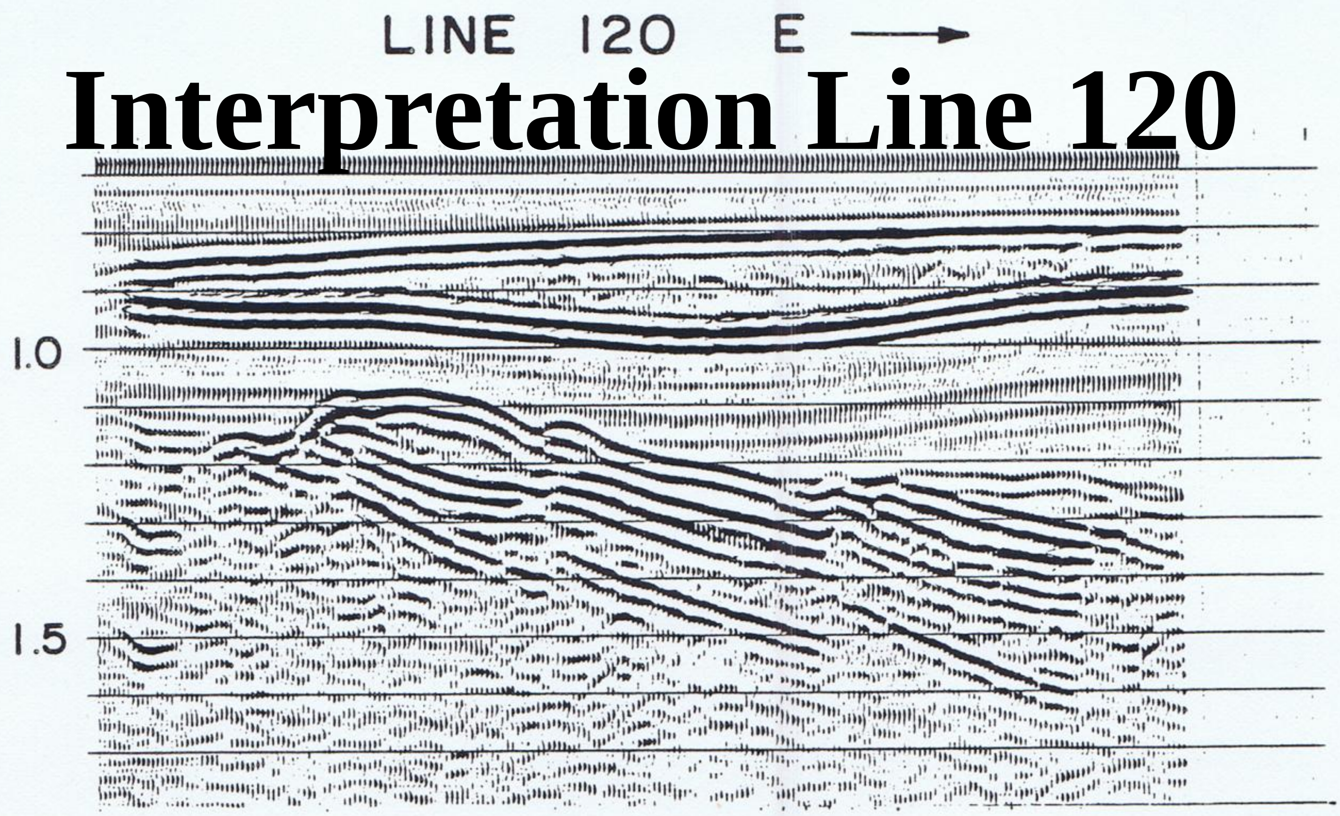


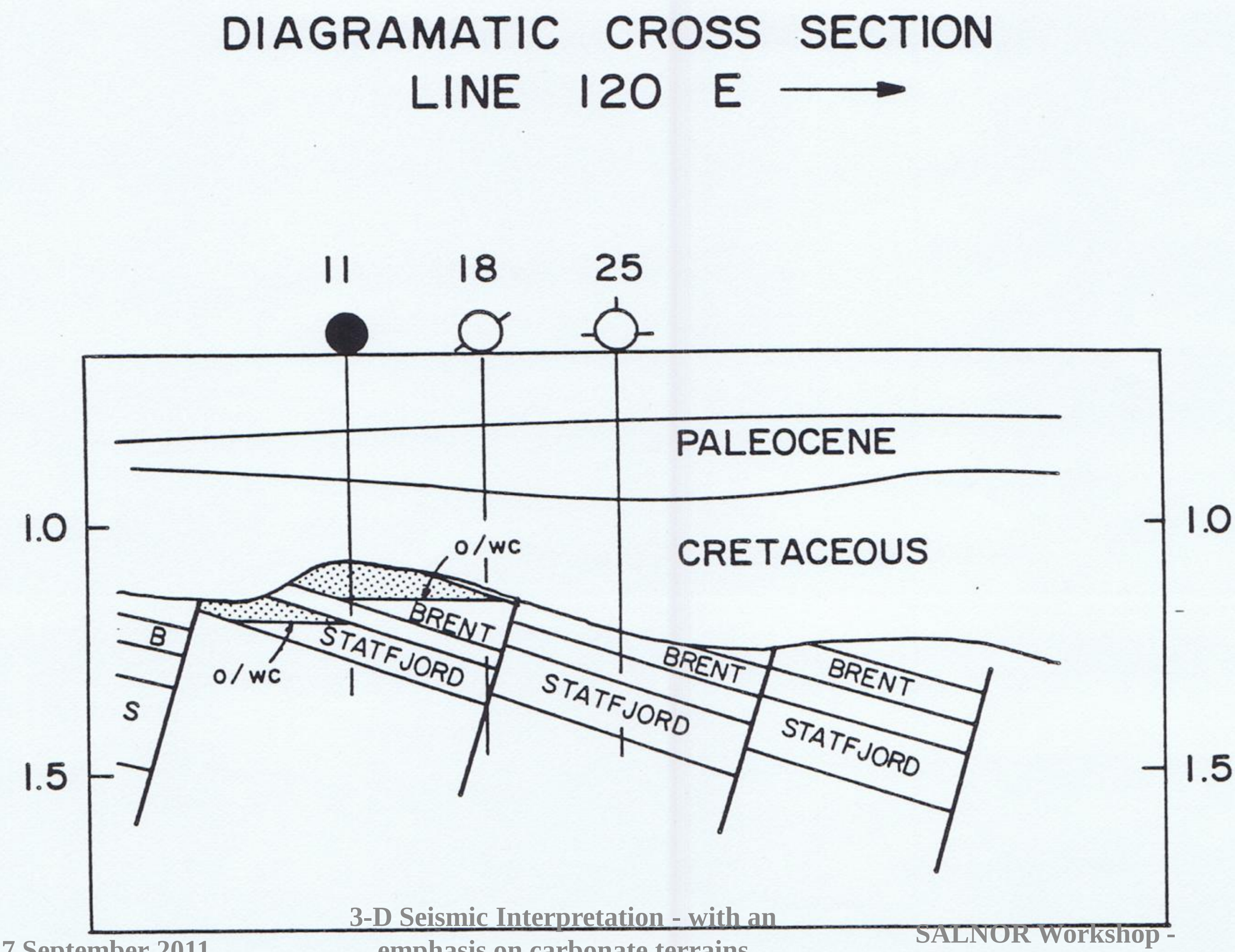
Interpretation Line 90



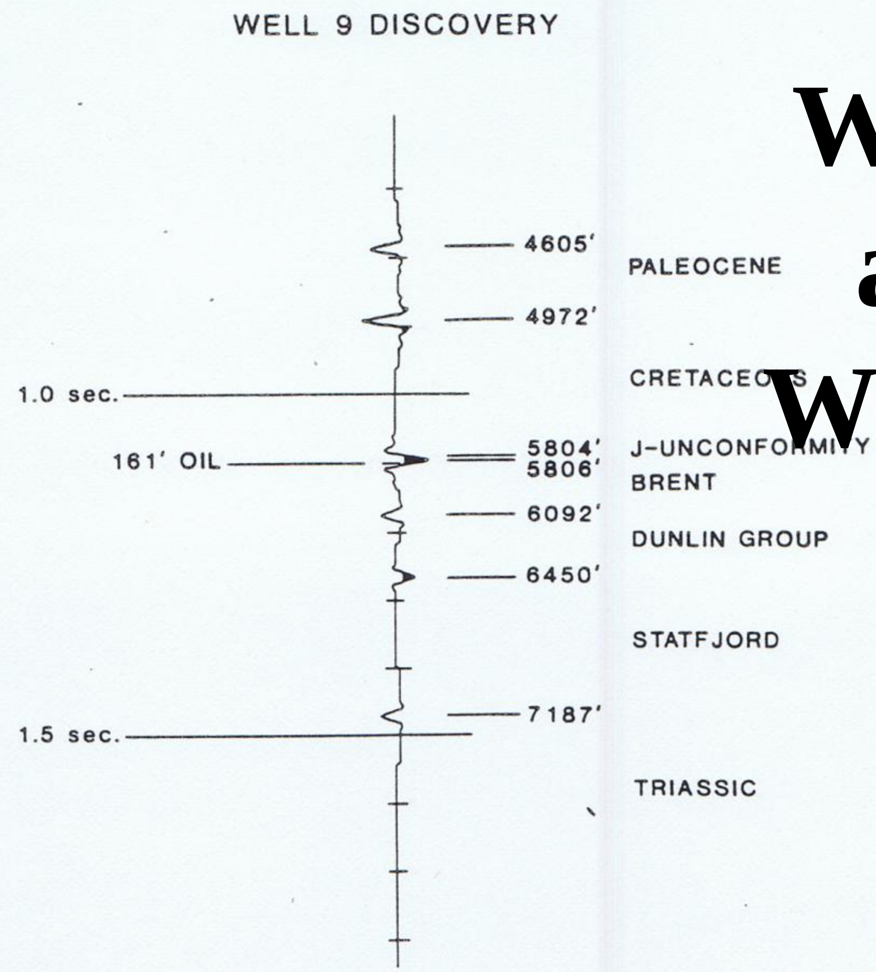


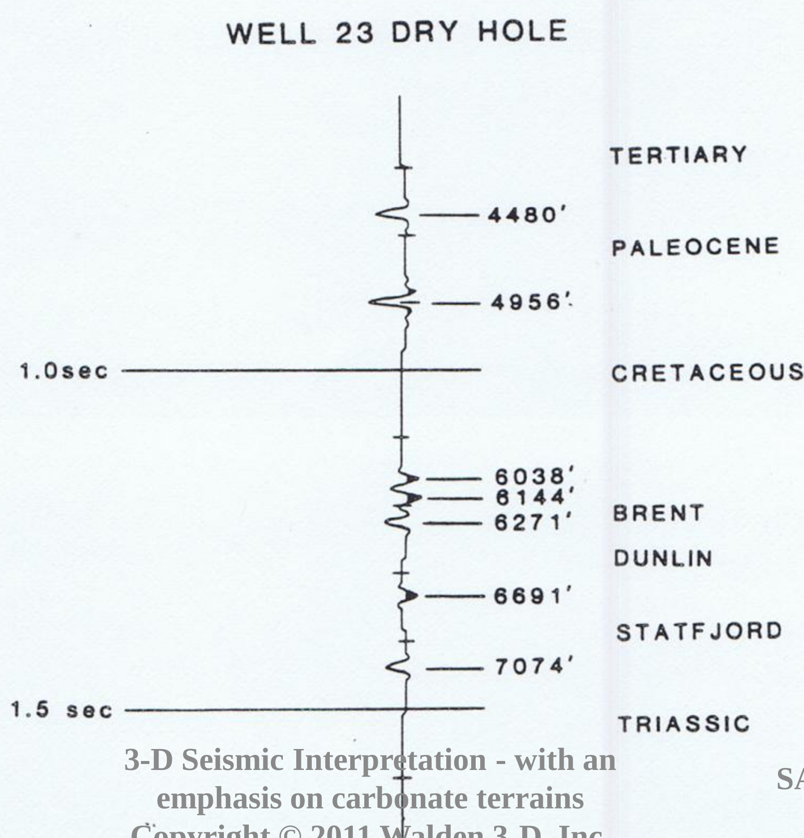
Interpretation Line 120



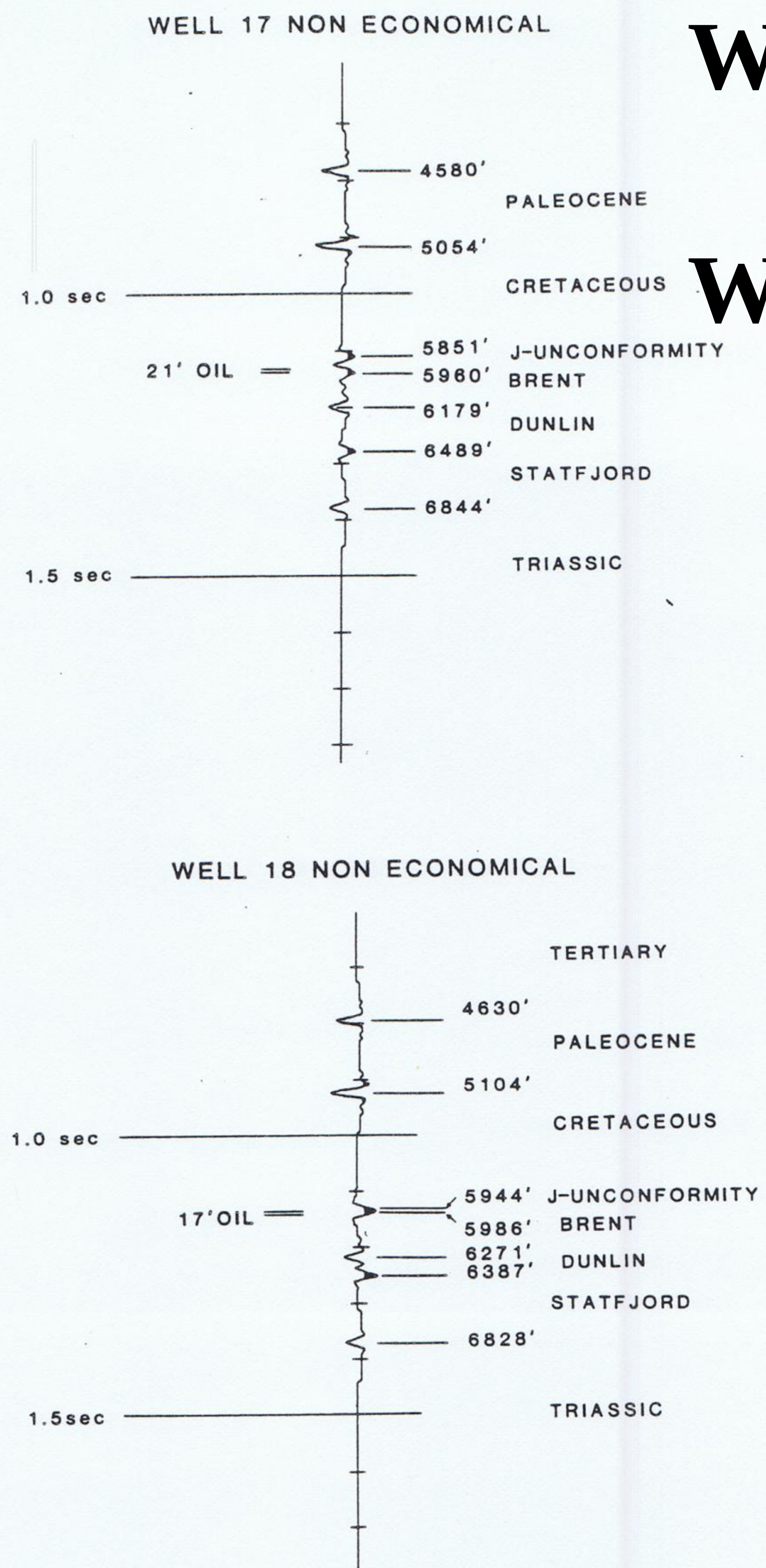


Well 9 and Well 23

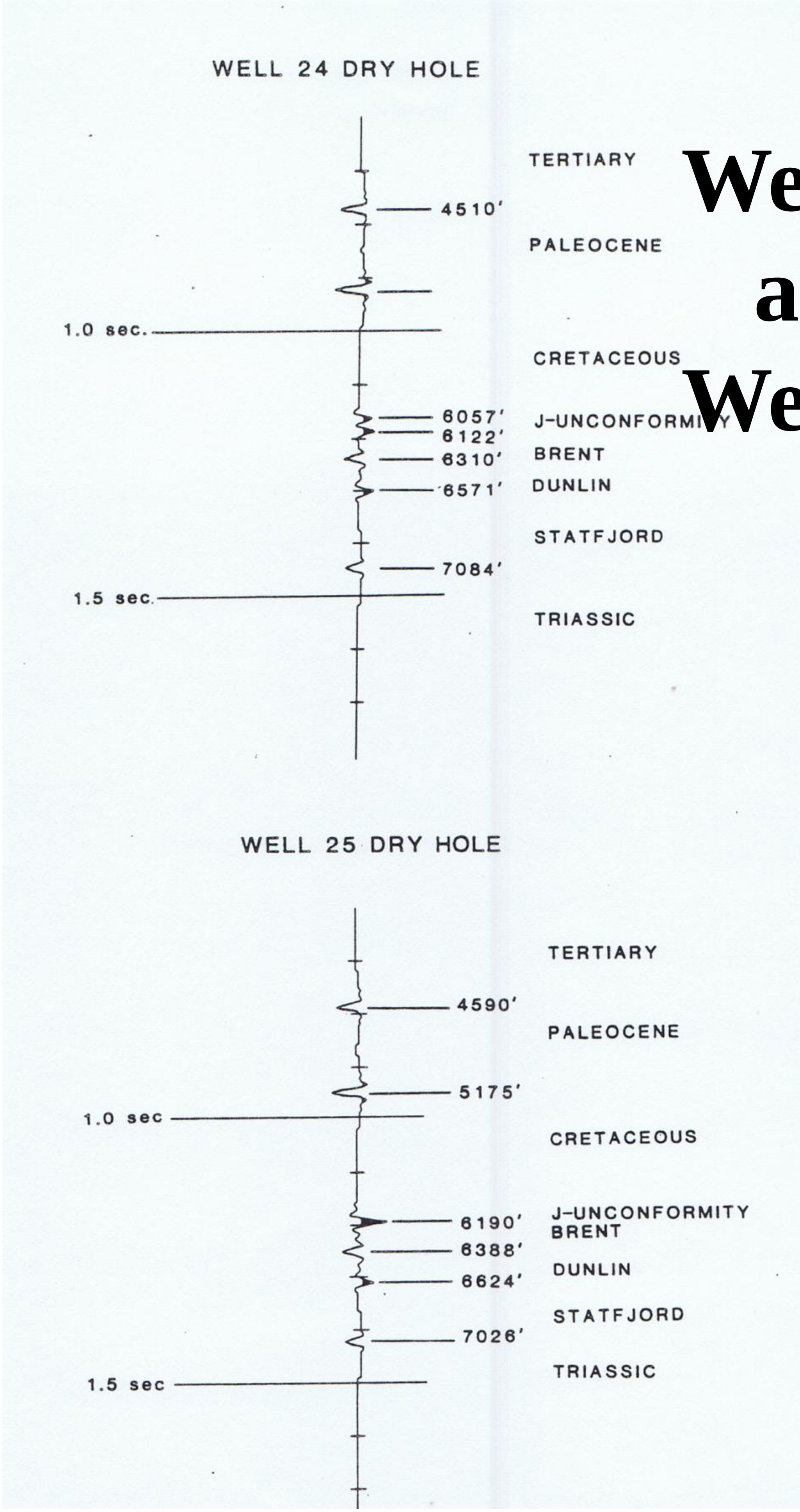




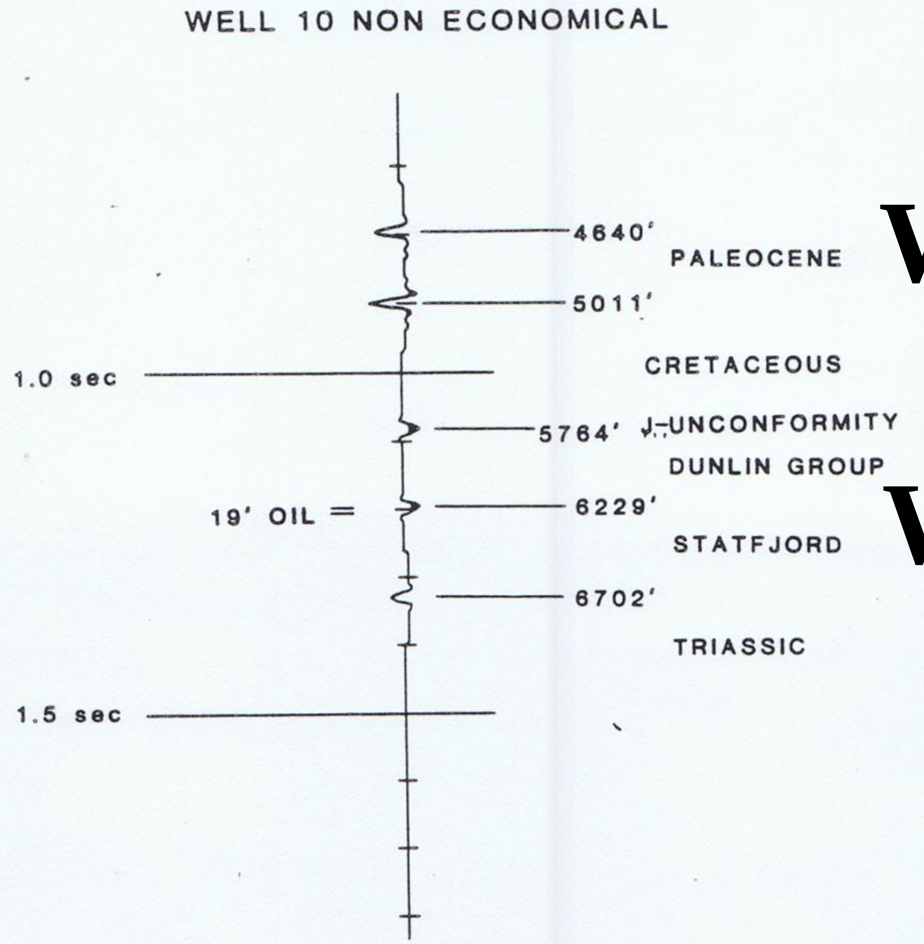
Well 17 and Well 18

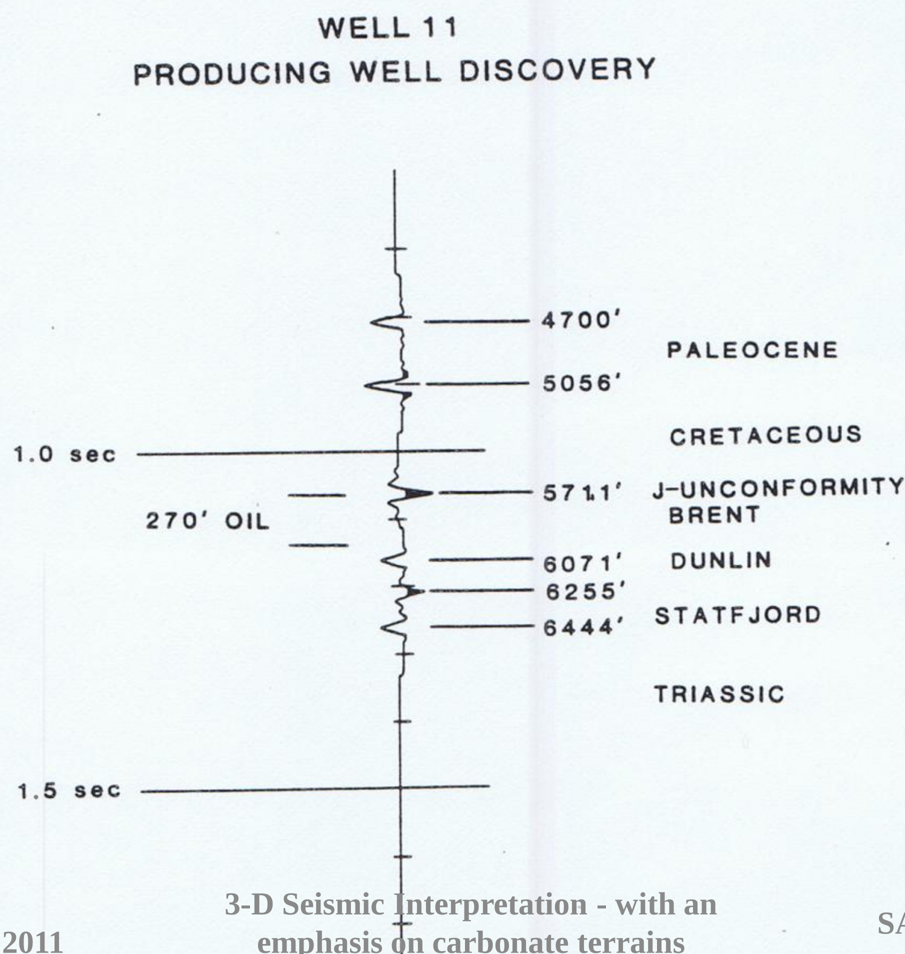


Well 24 and Well 25



Well 10 and Well 11





OTC 4511

North Sea Physical Model Construction, Data Acquisition, and Interpretation

by H.R. Nelson Jr.,* *Landmark Graphics Corp.*

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ABSTRACT

This paper describes the building, data acquisition and interpretation of a complex physical model, SALNOR, built to illustrate a "typical" complicated North Sea geological structural sequence. The model was built as a proprietary project for Statoil who then released it to the Allied Geophysical Laboratories (AGL). The model consists of seven layers that represent the Top Palcocene, Top Cretaceous, J-Uniformity, Top Brent, Base Brent, Top Stratfjord, and Base Statfjord. The respective model material used were 3120 (red), 184 (clear), 3110 (white), 3120, 3110, 3120, and 3110 RTV silicone rubber to represent pre-cretaceous rocks.

The steps required to build the model are detailed, along with photographs of the model as construction progressed. The 3D data set across the model consisted of 240 traces on 240 lines. Several other data sets across this model have since been collected. In order to graphically illustrate the complex structure, the model was cut into 16 square blocks. "Wells" were also cored in the center of each of these 16 blocks. This allows the seismic data to be directly tied to the reflection sources. It is interesting that when data was collected across the reassembled blocks, there was not excessive diffraction noise created by the vertical cuts and holes.

The initial interpretation was done on paper sections. Later the raw data and 3D migrated data were evaluated using the interactive interpretation capabilities of the Adage vector refresh graphics system. The interactive computer graphics interpretation is illustrated with a 16 mm movie. The movie specifically illustrates the value of rapidly animation through a sequence of vertical, horizontal or mixed vertical and horizontal seismic sections. The movement brings "alive" the geologic structures and stratigraphic sequences and allows the interpreter to make a rapid evaluation of the best prospects.

The model data can be used to evaluate and to teach different interpretation techniques. However the real value is the demonstrated ability of physical model data to accurately represent a complex offshore geological problem, and in the confidence this brings to marine seismic data acquired, processed, and interpreted in a parallel fashion.

INTRODUCTION

In late 1981 Ingebret Gausland from Statoil requested SAL to devise a workshop on 3D interpretation methods that interpreters working in the North Sea would find applicable to their work. It was decided that the best procedure would be to build a model that represented typical North Sea geology and structure and to base the workshop on it.[1] From this basic concept, the SALNOR model was designed. Figure 1 is a contour map of the only horizon that was contoured, the J-Unconformity. The two layers above this were to be flat, and the layers underneath of constant thickness dipping and parallel to each other within each separate fault block. Slight deviations from the planned dimensions occurred during construction and introduced an added degree of realism.

POST-J-UNCONFORMITY CONSTRUCTION

With the basic concept defined, the map was digitized on the Tektronix 4081 and displayed in 3D on the Adage. This allowed a visualization of the best way to put the different layers together. The contour map was scaled so that 1 in. = 1000 ft. In the next step, critical contours were cut out of plywood and stacked as shown in Figure 2, so that the exposed surface represented the bottom of the Cretaceous layer above the unconformity. The contour steps were then filled in with clay to form a smoothed inverse surface. A plaster cast was made of the clay surface, and represented the top of the J-Unconformity (Figure 3). Cretaceous (clear RTV) was poured on the positive plaster cast. The Top Cretaceous horizon was flat after this. However, because the modeling box was not tall enough for the plaster cast, the Cretaceous and the Paleocene, the clear RTV layer was supported on 3 blocks while the Paleocene (red RTV) was poured on top of it. As was discovered when horizontal sections were displayed, gravity warped the top Cretaceous around these three support points.

PRE-J-UNCONFORMITY CONSTRUCTION

The thick plaster mold for the J-Unconformity was key to building the lower layers of the model. Figure 4 illustrates how the plaster mold was shaved off with a carpenters plane to form the top of the first dipping layer, the Top Brent or Horizon 4. Note that the corner of the model at the bottom of the dip had been cut off. This corner was kept in it's original shape in order to make sure that the spacing between the plaster mold and the clear layer was correct. In order to pour the white RTV into the shaved space the model and modeling box were first turned up on one end. Then the plaster cast corners were clamped against the clear layer leaving a gap to pour into. Figure 5 shows the Horizon 4 after the pour had been completed.

Once the dip on the Top Brent was defined within each fault block, the plan was to keep all of the deeper horizons parallel so that there would be a constant thickness for each layer. To do this a set of holes was drilled into the plaster to the exact depth of the next layer. Next a plane was used to shave off the plaster to the bottom of the holes. The biggest problem with this was that the composition of the plaster was not constant. This resulted in portions shaving off faster than others. Also, the drill holes filled up with shavings, and it was hard to determine when the proper level had been reached. However, a fair approximation was made, and red material poured into the void to form the Brent Sandstone. The red RTV is viscous and it was hard to get it to flow all the way to the end of the pinchout against the J-Unconformity. The thinnest portion of the pinchout had to be repoured for this layer.

The same procedure described above was used to modify the plaster mold for the Top Statfjord or Horizon 6. The void between the Brent and Statfjord was filled with white RTV. The plaster was then shaved off a last time to form the Base Statfjord or Horizon 7. The fact that the holes drilled to determine how far to shave off the plaster filled up with plaster shavings was not realized until the silicone rubber model and the plaster were separated. Although the horizons were flat, the thicknesses varied more than planned. The Statfjord was also made of 3120, red RTV. A layer of white, parallel to the top surface was poured on this to represent basement (Horizon 8).

With the faulted portion of the model completed, the last construction step was to pour the corners (Figure 6). Both corners were filled with 3 flat layers that were parallel to the Top Paleocene and Basement. These horizons were named the Top Brent, Base Brent and Basement. The Brent was red silicone rubber and the layers on either side white. When the model was completed it was placed on the wire platform in the Seismic Acoustics Laboratories Physical Modeling Tank[2] for data acquisition.

DATA COLLECTION AND ACTUAL MODEL MAKEUP

Seven sets of data were collected across the SALNOR model.[3] This data includes common offset and multifold lines in different direction, as well as parallel and cross-spread areal surveys. The common offset 3D survey with 240 traces on each of 240 parallel lines is the basis for the examples used in this report. This is model SALNOR-7 in the catalog. The trace locations from a 100 foot scaled grid that covers the square model, 24,000 feet scaled on a side.

When these data were analyzed, it became obvious that there were some unexpected deviations from the original design. The most glaring example was the varying thickness of the Paleocene layer as described above. To measure these differences and to illustrate the complexity of the model, it was decided that the model would be cut into 16 blocks. Also, 49 "wells" were measured or cored to further define the model. A stylized geologic cross-section through 11 synthetic seismic traces generated from measurements of some of these wells is illustrated in Figure 7. The first few wells that were drilled had problems, in that the core disintegrated. However, this was solved for most of the other wells. Figure 8 shows the location of 7 cross-sections that were made directly from the cuts across the model. Three of these cross-sections are shown in Figure 9. The model does closely meet the original design.

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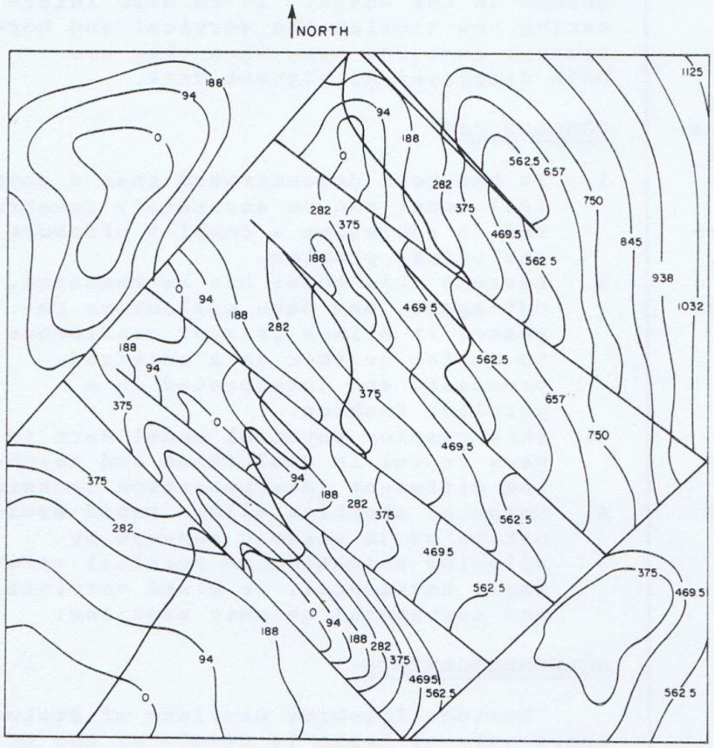

Fig. 1—Map design for J-unconformity (Horizon 3).

Fig. 2—Plywood model of critical contours defining J-uniformity (Horizon 3).

Fig. 3—Plaster cast of J-unconformity (Horizon 3).

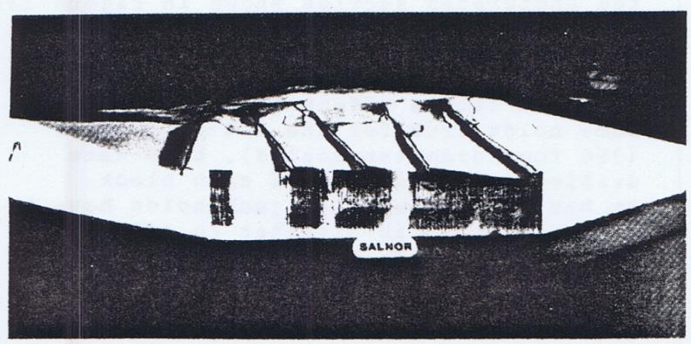

Fig. 4—Plaster cast of Top Brent (Horizon 4).

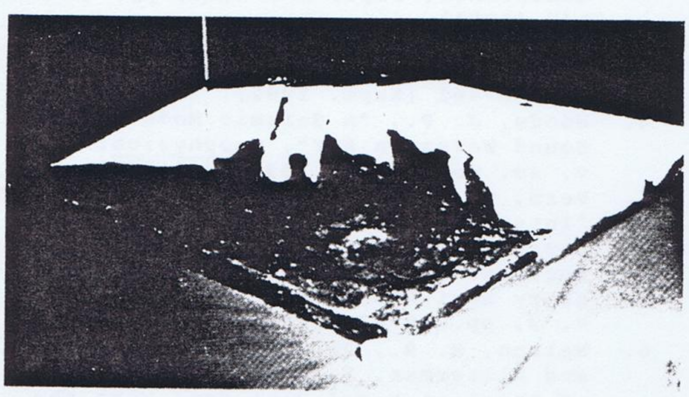

Fig. 5—The silicone rubber model where Top Brent (Horizon 4, White) pinches out against J-unconformity.

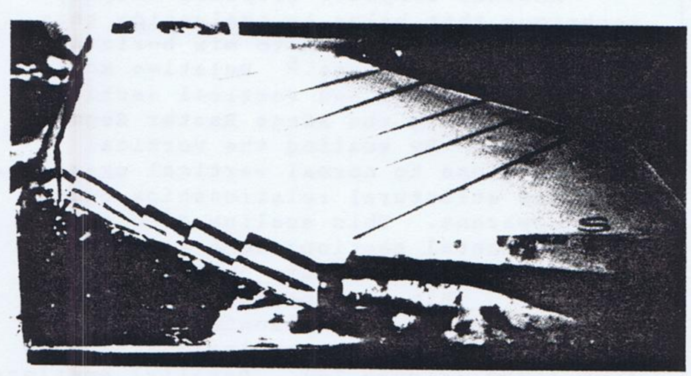

Fig. 6—An end-on view of the model, showing Brent and Statfjord sands.

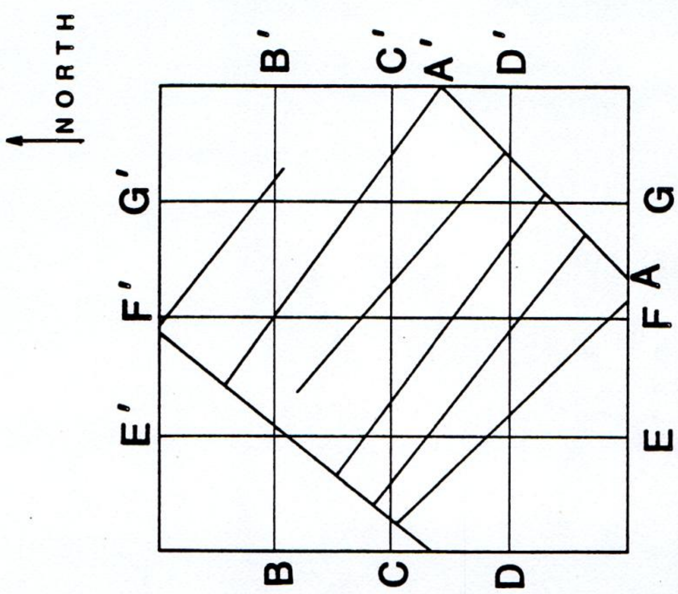

Fig. 8—Cross-section location map.

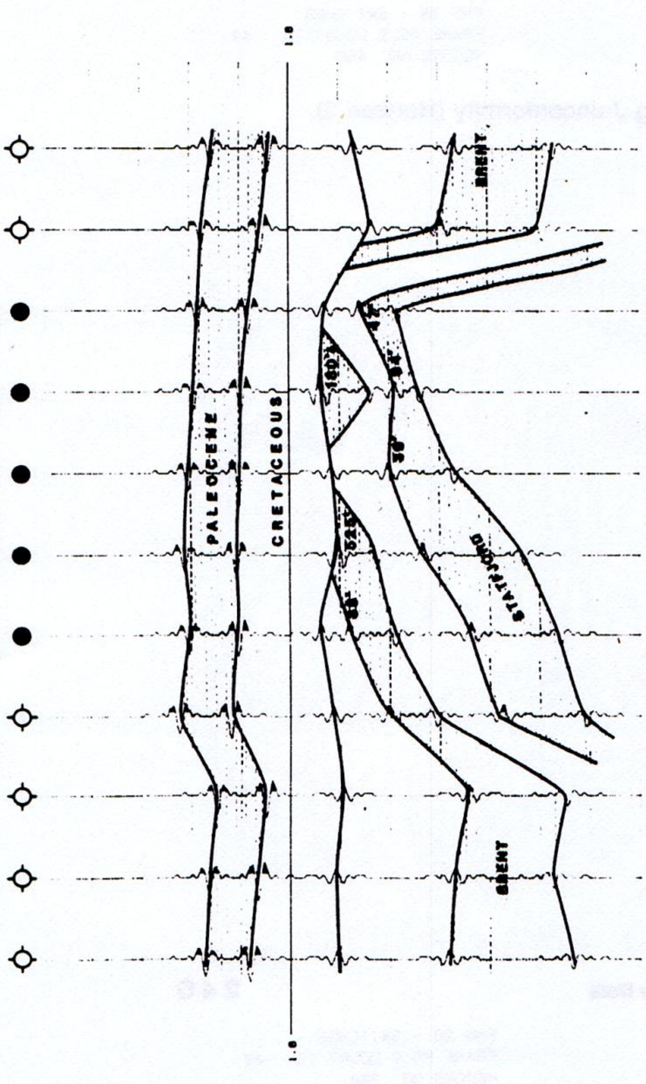

Fig. 7—A geologic cross-section based on sample synthetic seismic traces.

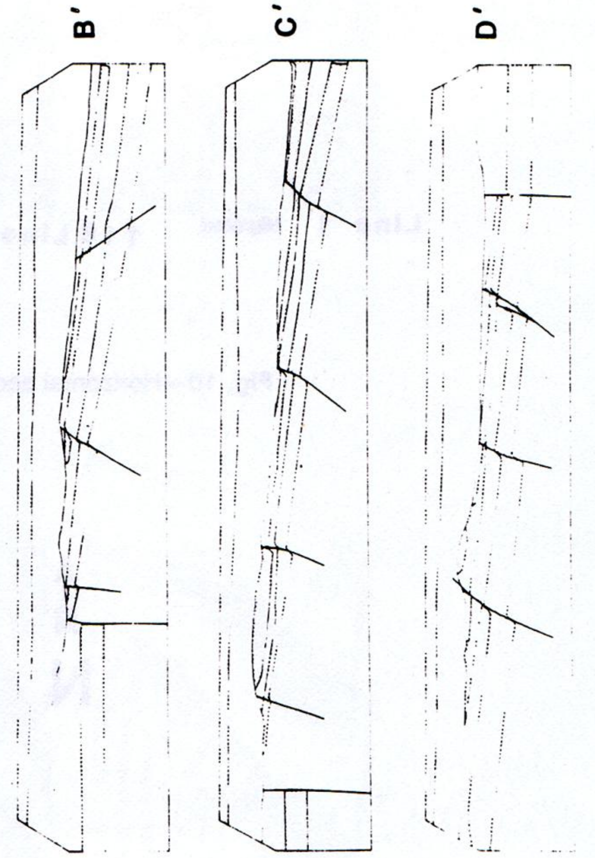

Fig. 9—Traced cross-sections B-B′, C-C′, and D-D′.

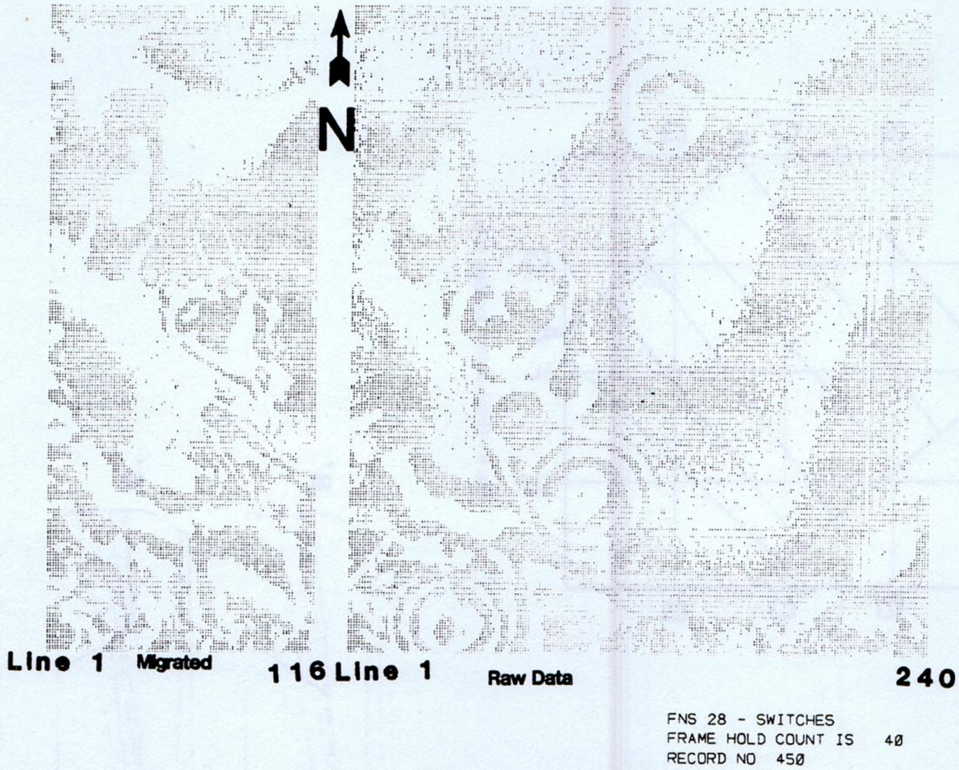

Fig. 10—Horizontal section cutting J-unconformity (Horizon 3).

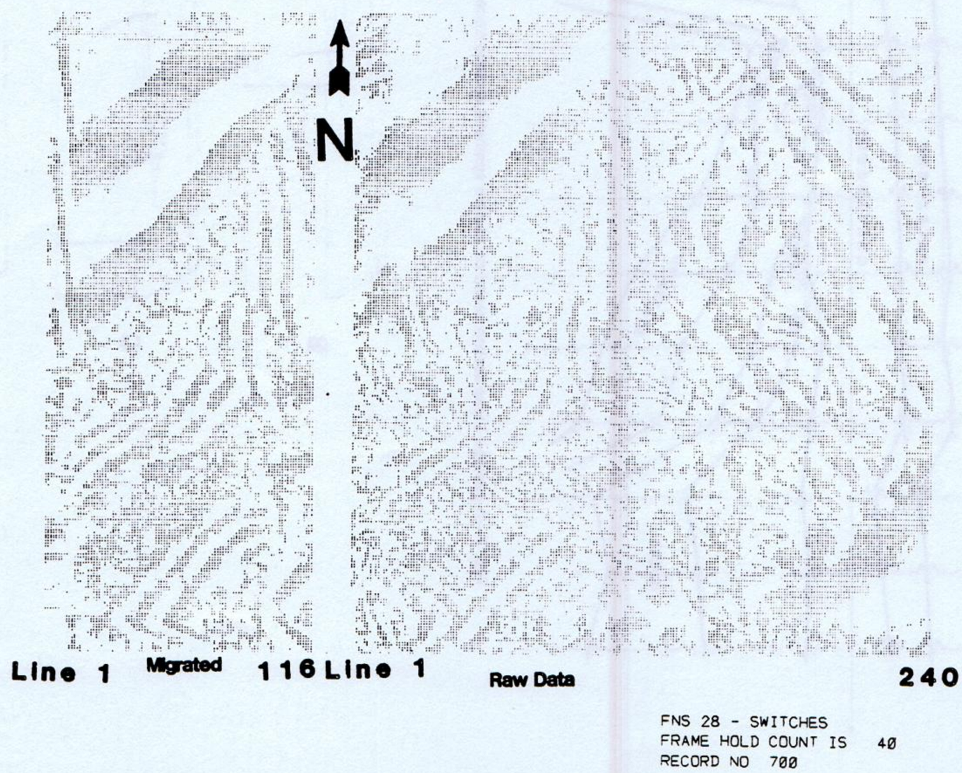

Fig. 11—Horizontal section showing fault blocks and flat Brent sandstone corner layer (Horizon 9).

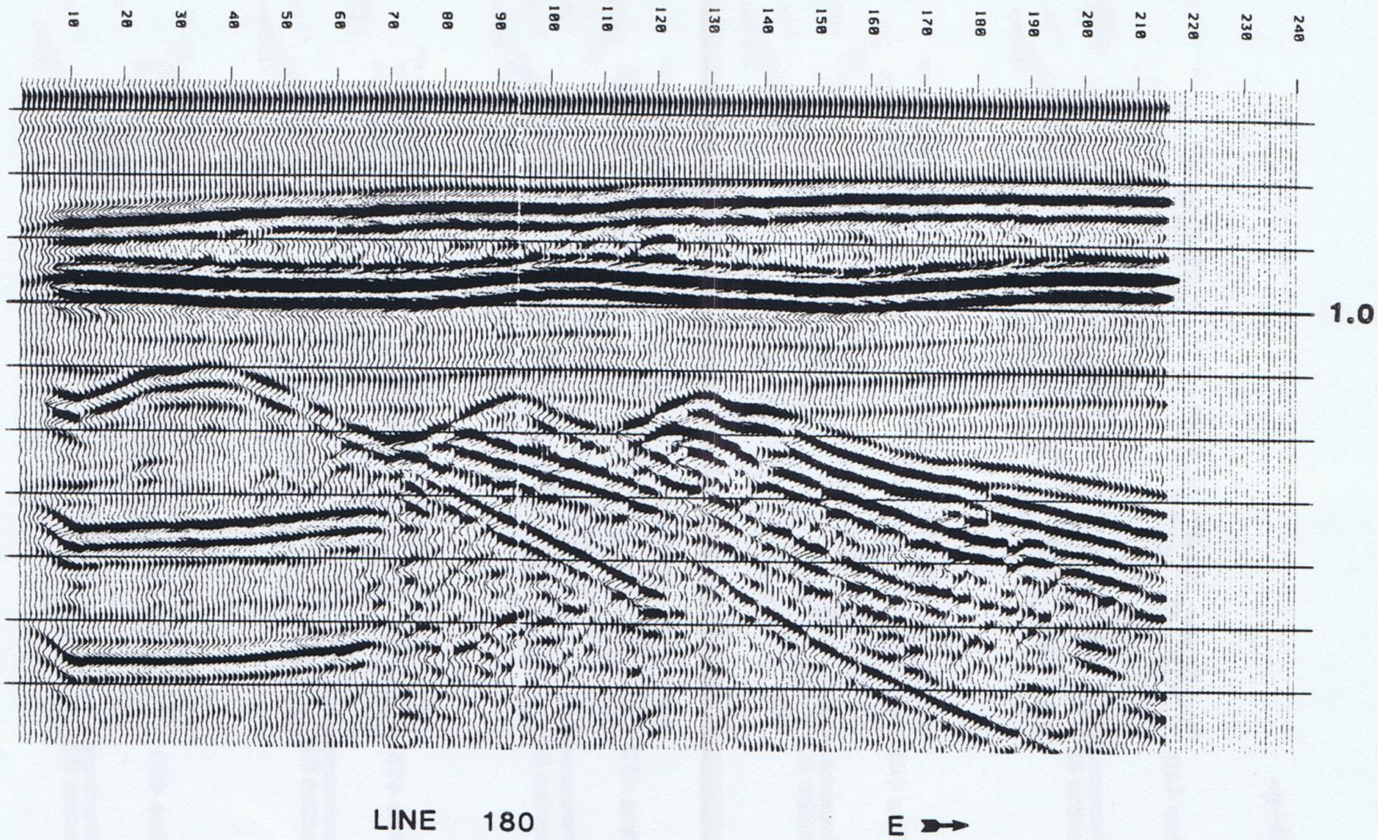

Fig. 12—Vertical section [180 E-W (B-B[1])].

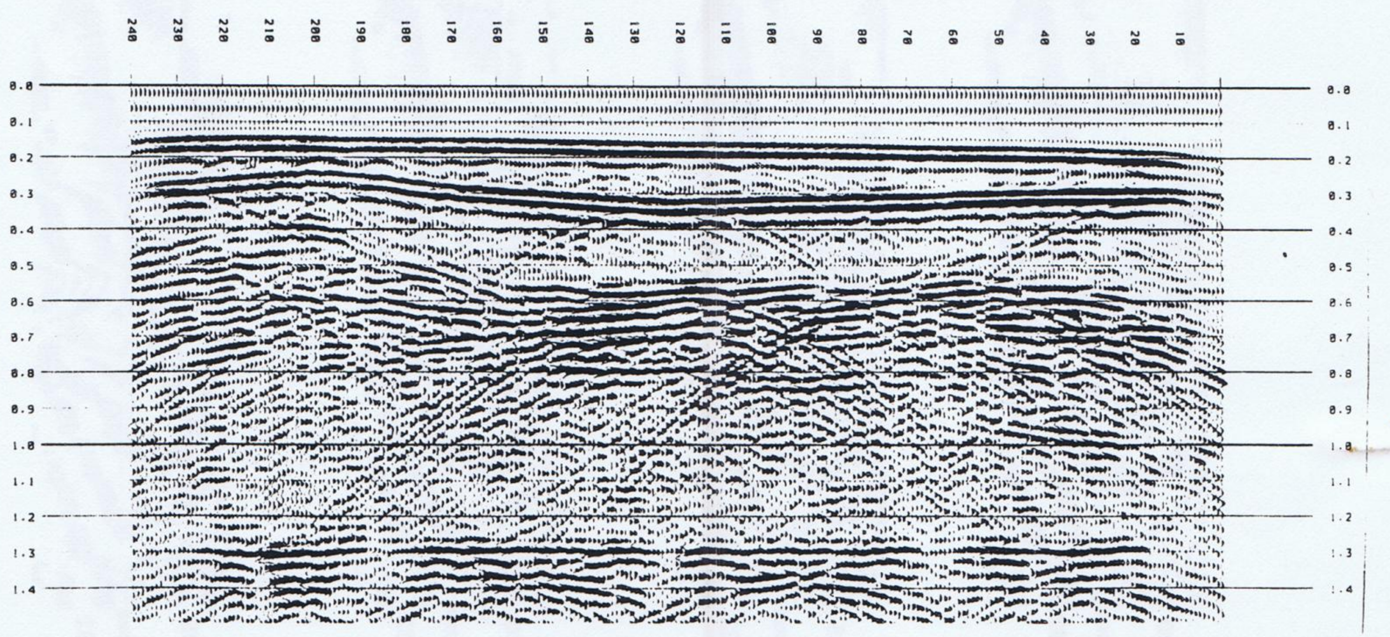

Fig. 13—Vertical section 228 across reassembled model.

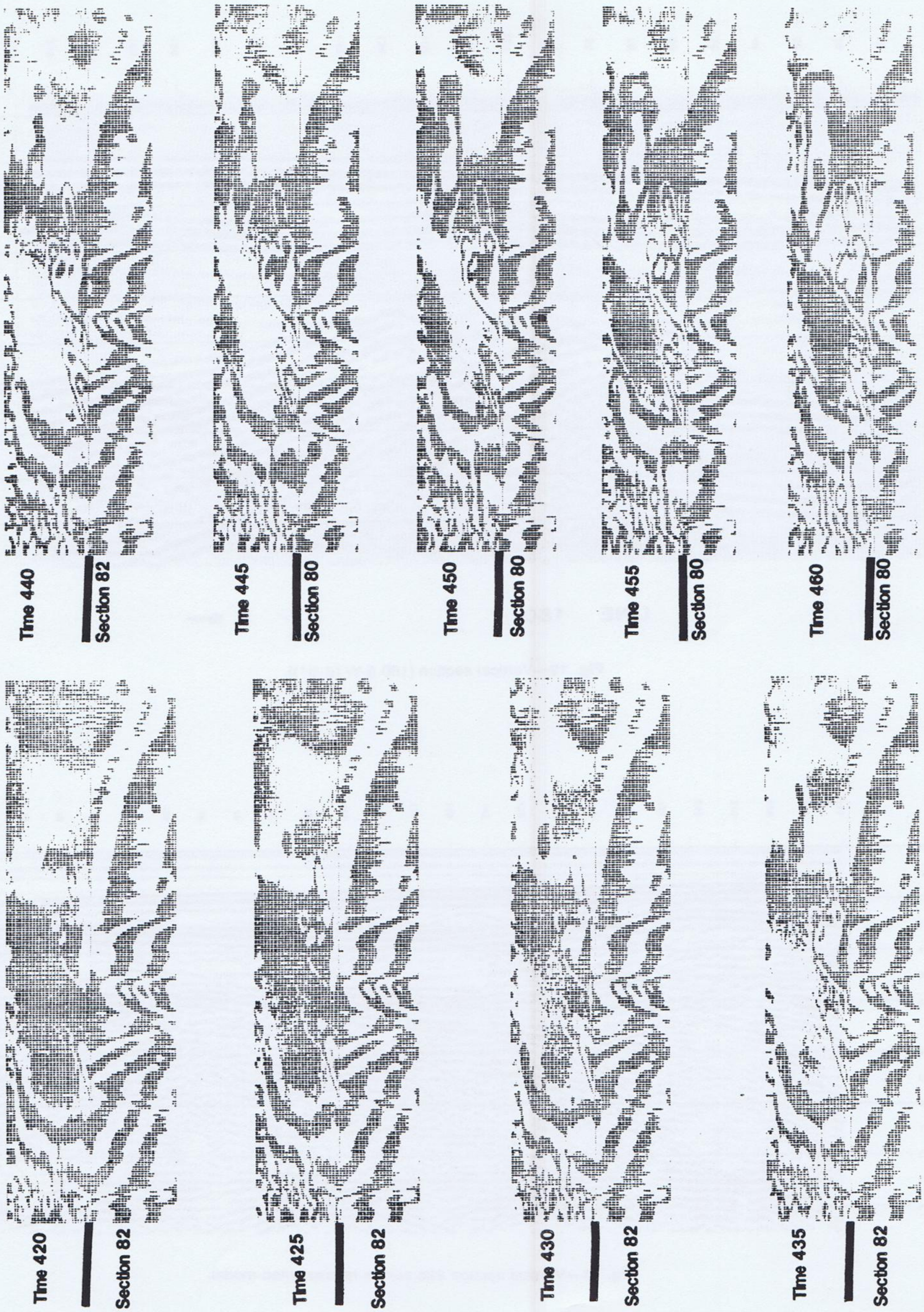

Fig. 14—Mixed animation sequence—horizontal sections range from 401 to 435 ms, and vertical section 82.

Thank You