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THE DETECTION OF GASEOUS HYDROCARBON ACCUMULATIONS BY SEISMIC INTERFERENCE PATTERNS AND LATERAL VELOCITY VARIATIONS

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INTRODUCTION

Seismic interference, or what is often called "noise," is recorded simultaneously with reflected energy and becomes an intrinsic part of a record section. The interference is generally from two sources; one generated near or at the surface by the energy source, and the other in the subsurface, returning a wave form known as a diffraction.

Noise lacks the continuity of reflected returns and various techniques are used to lessen its intensity. The level of noise created at the surface can be effectively reduced, but not eliminated, by frequency filters during processing and by varying the field parameters. Diffractions, however, respond as reflections and are likely to be enhanced as the surface noise level is lowered.

Vertical velocity is the average speed of the accoustical wave between the surface and each reflecting horizon. These velocities, prior to computer usage and common depth point recording, were obtainable only at wellsites. Today, it is a common practice of seismic processing centers to convert reflection times into velocity. These values are computed at common depth point stations and are known as "RMS Velocities." The RMS values, although they lack the accuracy of velocities computed at wellsites, are useful in that they provide information concerning lateral velocity changes on a seismic cross-section.

DIFFRACTION INTERFERENCE PATTERNS

Diffractions are waves recorded from isolated points in the subsurface and they originate where there is an abrupt change in lateral velocity. For reasons that are not too well known, the energy from the surface source will cause the beds at this point of change to oscillate and the point of change will be an energy source in itself. The phrase "Point Source of Energy" and the word "Diffraction," therefore, are synonymous as to source and can be used interchangeably.

A diffraction is a reflection with a definite shape and character. Figure 1 has diffractions shaded within the oval outline. In complete form the diffraction will have an umbrella shape, convex towards the surface. Characteristically, the entire diffraction is rarely reproduced on the record section and will be recorded only in segments. These segments are, in geophysical jargon, "Reflections With Too Much Curvature." Segments of diffractions, however, are in abundance whenever there is a source, and can easily be identified by their curved appearance.

The best known source for a diffraction is along a fault plane where beds of differing velocities are in juxtaposition. The entire fault plane will have a large number of sources and seismic interpreters will use their diffractions to locate and position faults. The pinch-out point of a sandstone bed within a shale is also a potential source for diffractions, as is the termination of a bed at an angular unconformity. I am sure that other sources can be thought of. Of interest though, is that in recent years interpreters have speculated that when gas is trapped in a reservoir, the gas-fluid interface will provide a velocity contrast that will create diffractions.

Seismic interference, generated from either the surface or subsurface, will often form an area of disturbance that can be recognized and outlined on the seismic cross-section. This area, when it is subsurface in origin, is what I have termed to be a "Diffraction Interference Pattern." Diffraction energy, once initiated, is repetitious and will expand with time. Therefore, the shape of the pattern will often be conical with the apex pointed towards the surface.

Figure 1 displays a seismic section about four miles long and centrally located in the Wind River Basin. This structure has been tested near the crest of the fold. This feature is capable of producing commercial amounts of gas from more than one sandstone reservoir in the Lower Fort Union Formation. The oval shaped Diffraction Interference Pattern, outlined near the crest of the fold, is subsurface in origin and contains a large number of diffractions. The interference is strong enough, within the outline, to break the reflection continuity at the base of the Waltman Shale. The diffractions completely destroy the reflections recording the top of the Mesaverde and, though weaker, are present at the base of the section. The slight distortion of the reflections recording the Lower Cretaceous and Paleozoic Sections are probably not related to this interference pattern.

The width and shape of the oval interference pattern and the intensity of the diffractions contained within, is not a pattern typical of the type associated with faulting. It is

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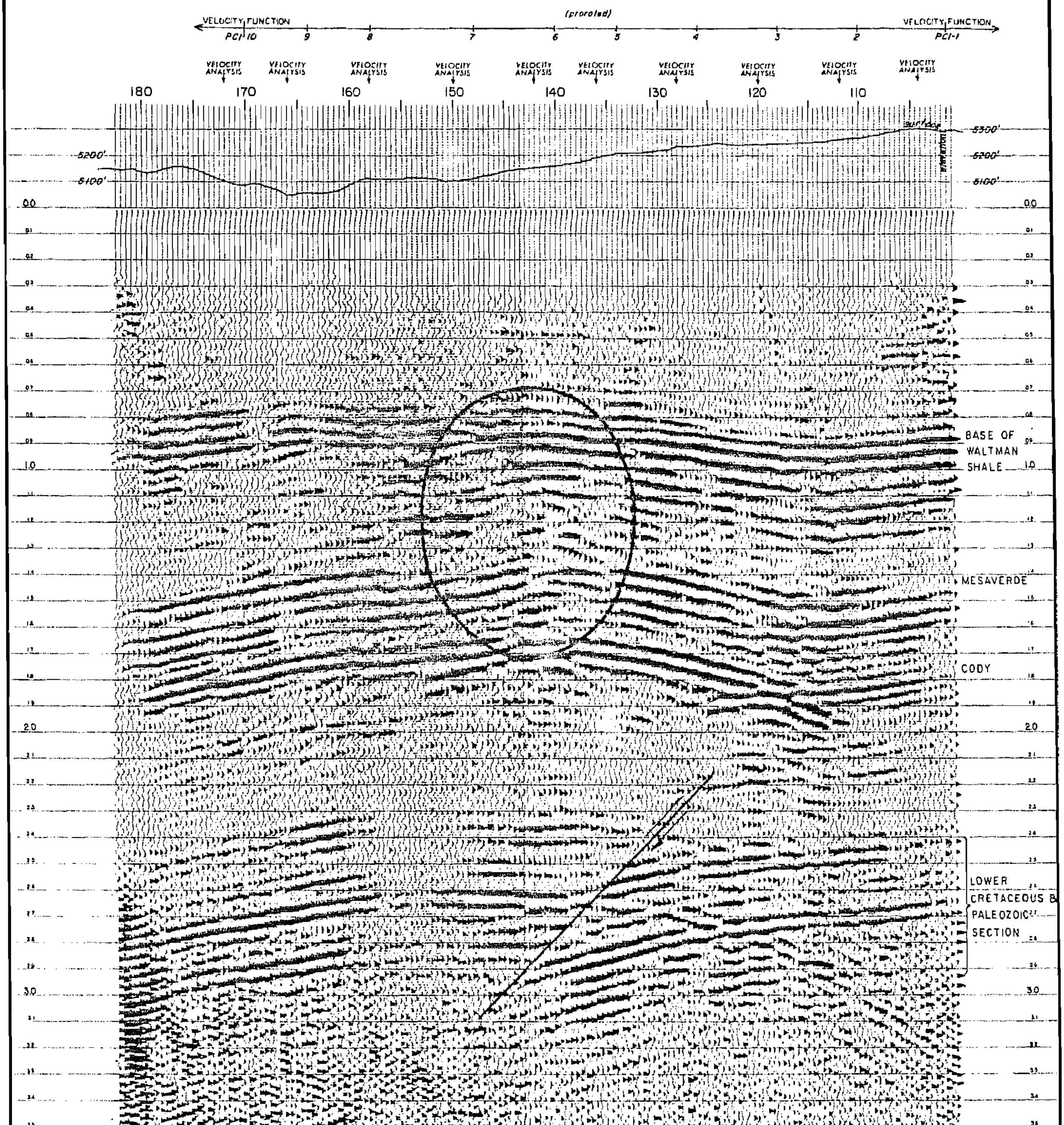

FIGURE 1 A 6 FOLD SEISMIC SECTION IN THE WIND RIVER BASIN, WYOMING, ILLUSTRATING HOW DIFFRACTIONS WILL COMPOSITE INTO A DEFINABLE PATTERN.

more likely, in this case, that the point source of energy is related to the gas contained in the Lower Fort Union Sandstones. Where and how the diffractions originate is a matter of speculation. The significance is that the pattern approximates that portion of the section where we can expect gas accumulation. The pattern cannot delineate the number of sands containing gas, nor does it imply a relationship as to the quantity of gas contained.

LATERAL VELOCITY VARIATIONS

Arthur Pollet (1974) shows by means of a velocity model, Figure 2, the configuration iso-velocity contours would have beneath a low velocity layer, introduced at a time of 1600 ms. His model is based on a typical clastic Gulf Coast Tertiary Section. The solid rectangular slab represents a sandstone bed, 100 feet thick, and is assumed to be gas saturated. The time delay, caused by the gas lowering the velocity in the sandstone, is .013 seconds, two-way time. Lines X and X' connect troughs of low velocity and Y and Y' are lines through peaks of high velocity. All four of these axes are spurious and are created by transition effects as the energy source moves across the introduced lower velocity layer. Line A joins troughs of the expected lower velocity beneath the rectangular slab.

Figure 3 (Pollet, 1974) is an actual example of a velocity analysis performed on an offshore Louisiana section. Lines X, Y, Y' and X' again define the spurious low and high velocity trends associated with the low velocity material in the dashed outline. As in Figure 2, line A connects troughs representing an authentic iso-velocity low.

Figure 4 is the iso-velocity cross-section for Figure 1. Control points are from the twelve velocity analysis stations shown in the heading and the computational methods are similar to that used for Figures 2 and 3. The iso-velocity configuration is remarkably similar to the offshore example in Figure 3. The spurious axes X, Y, Y', and X', are present and well defined, as is axis A, representing the true, low velocity anomaly. The slower velocity along axis A has further support from the well drilled near velocity

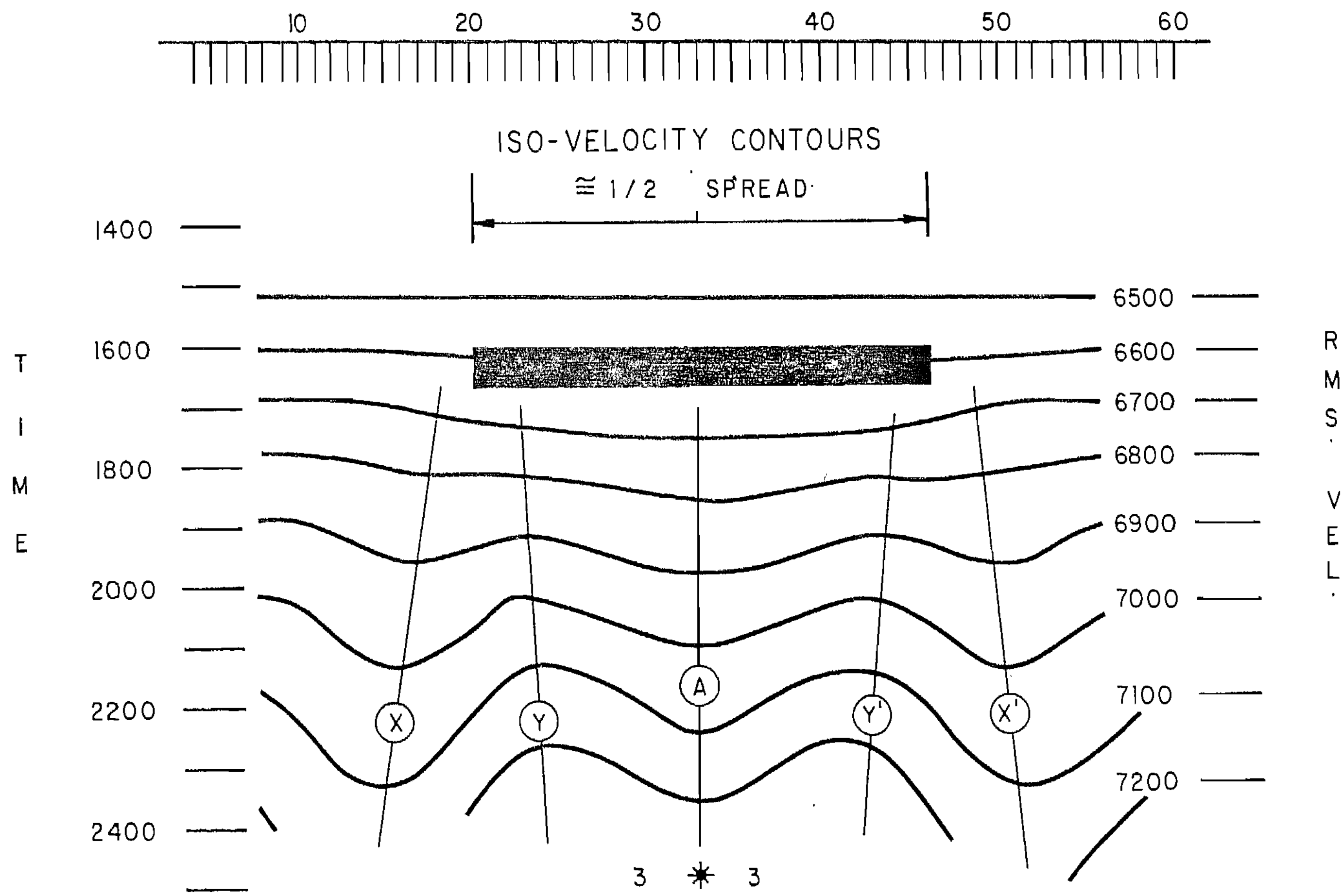

FIGURE 2 ISO-VELOCITY SECTION MODEL OVER A LOW VELOCITY LAYER WHOSE LATERAL EXTENT EQUALS ONE HALF SPREAD LENGTH.(POLLET, 1974)

station 142. The integrated sonic log measures the average velocity to the Mesaverde Formation as approximately 10,500 feet per second, which is considerably slower than regional for this area.

It is also evident from Figure 4, that the outlined Diffraction Interference Pattern and the velocity low along the A axis have a common relationship to the gas contained in the Lower Fort Union Sandstones. The Interference Pattern is located on the A axis and encircles that part of the section where iso-velocity contours are showing an accelerated rate of velocity decrease. The integrated sonic log and gas production from the Lower Fort Union Section support this analysis.

SUMMARY

The interpretive technique of combining a lateral velocity analysis with a diffraction interference study is one of many methods now commonly used to directly read hydrocarbons. Other significant methods that have recently assumed importance, include studies of reflection amplitude variations, anomalous isotime thicks and unusual structural sags on regional dip lines. All of these are important observations and should be an integral part of a seismic interpretation. This paper, in reality, is a case history of a well successfully testing a good structural anomaly. It may be somewhat unique in that both the

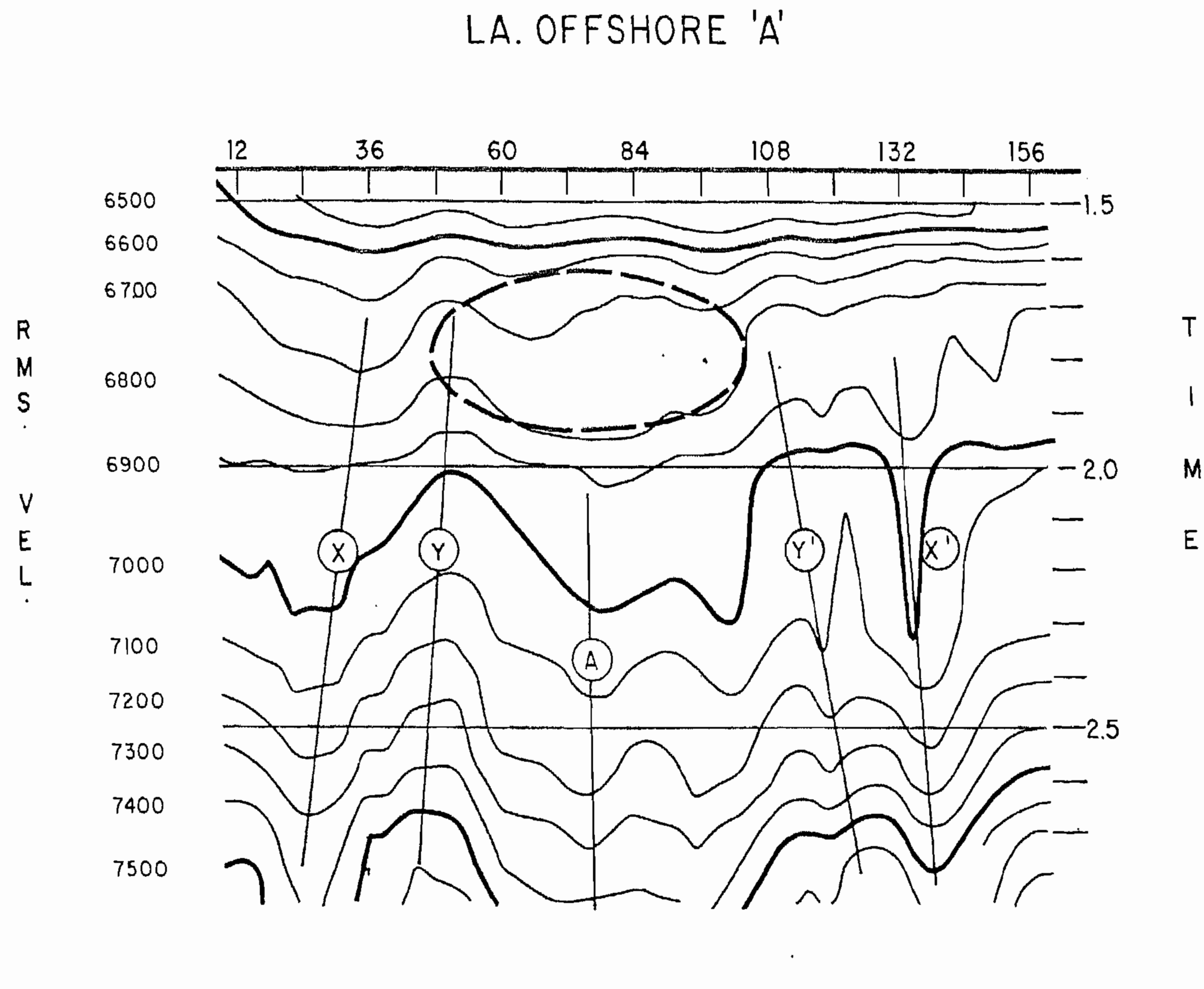

FIGURE 3 ISO-VELOCITY SECTION VELOCITY ANALYSIS ACROSS SECTION 'A'. 4 PT. COMPOSITE, 3 PT RUNNING AVERAGE. LINES X, Y, X' AND Y' INDICATE SPURIOUS VELOCITY VARIATIONS ASSOCIATED WITH LATERAL CHANGES IN VELOCITY (POLLET, 1974).

velocity analysis and the diffraction interference study provided an additional incentive for drilling. It is especially gratifying that the results confirmed the velocity predictions and supported the idea that gas would be encountered in the Lower Fort Union Section. These direct-reading techniques, when applied to areas in the Wind River Basin where structures are not the prime trapping mechanism, can be very helpful in high grading locations for stratigraphic drilling.

REFERENCES CITED

Pollet, Arthur, 1974, Simple Velocity Modelling and The Continuous Velocity Section, preprint, 44th Annual International Meeting, Society of Exploration Geophysicists, Dallas, Texas.

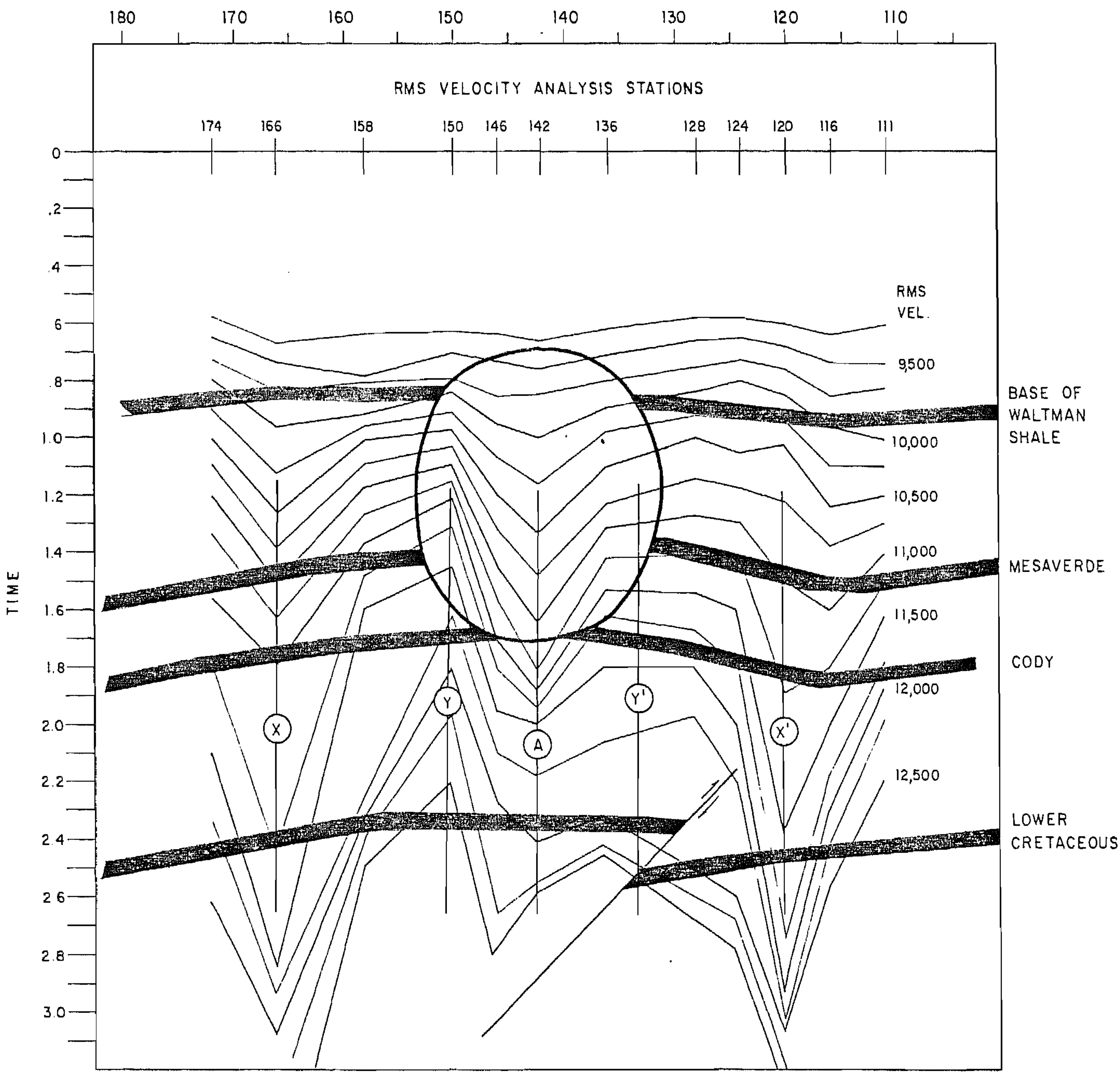

FIGURE 4 ISO VELOCITY SECTION FOR FIG 1. SPURIOUS VELOCITY VARIATIONS ARE SHOWN BY LINES X,Y,X' & Y' AND THE ANOMALOUS LOW VELOCITY BY LINE A.